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SCIENTIFIC INVOLVEMENT IN SKYLAB BY THE  
SPACE SCIENCES LABORATORY OF THE  
MARSHALL SPACE FLIGHT CENTER

Edited by Carl E. Winkler  
Space Sciences Laboratory

February 28, 1973

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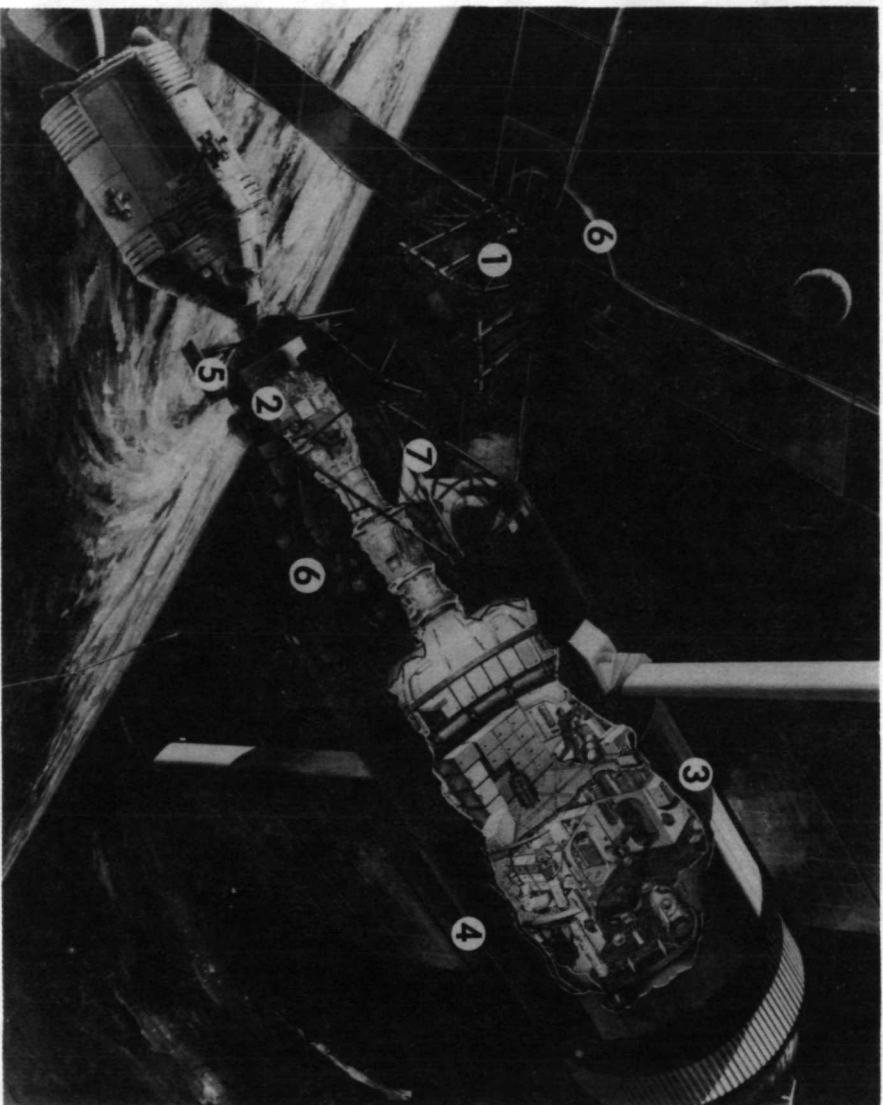
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16. ABSTRACT  <p>This report briefly describes the involvement of the Marshall Space Flight Center's Space Sciences Laboratory in the Skylab program from the early feasibility studies through the analysis and publication of flight scientific and technical results. This includes Mission Operations Support, the Apollo Telescope Mount, Materials Science/Manufacturing in Space, Optical Contamination, Environmental and Thermal Design Criteria, and several corollary measurements and experiments.</p> <p style="text-align: center;">EDITOR'S NOTE</p> <p>Use of trade names or names of manufacturers in this report does not constitute an official endorsement of such products or manufacturers, either expressed or implied, by the National Aeronautics and Space Administration or any other agency of the United States Government.</p>			
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## PREFACE

A major portion of the work described in this report was accomplished during the past three years. During this period the Marshall Space Flight Center's (MSFC) Space Sciences Laboratory (SSL) was experiencing a transitional phase of priorities under the able leadership of Gerhard B. Heller, who served as laboratory director from 1969 until his death in October 1972. Under his guidance, the emphasis in SSL was geared almost entirely toward recognized involvement in MSFC-approved projects. Two factors have brought about this change in priorities: (1) the increasing importance given to scientific experiments in space by NASA following the Apollo Program, and (2) the maturing efforts of several research teams involving SSL scientists over a broad spectrum of disciplines. Much credit for the latter belongs to the influence of the late Mr. Heller. This report is evidence of the SSL's role in one of MSFC's approved programs — the Skylab.



### **1 ATM:**

WHITE LIGHT CORONAGRAPH S-052  
X-RAY SPECTROGRAPHIC TELESCOPE S-054  
UV SCANNING POLYCHROMATOR/SPECTROHELIOMETER S-055A  
X-RAY TELESCOPE S-056  
XUV SPECTROHELIOGRAPH S-082A  
SPECTROGRAPH AND XUV MONITOR S-082B  
HYDROGEN ALPHA TELESCOPE

### **2 MS/MS:**

MATERIALS PROCESSING FACILITY M-512  
METALS MELTING M-551  
EXOTHERMIC BRAZING M-552  
SPHERE FORMING M-553  
GALLIUM ARSENIDE CRYSTAL GROWTH M-555  
VAPOR GROWTH OF IV - VI COMPOUNDS M-556  
RADIOACTIVE TRACER DIFFUSION M-558  
SPHERICAL CRYSTAL M-560  
GROWTH OF MIXED III - IV COMPOUNDS M-563  
COPPER-ALUMINUM EUTECTIC M-566

### **3 SOLAR SCIENTIFIC AIRLOCK:**

GEGENSCHEN/ZODIACAL LIGHT S-073  
ATM CONTAMINATION MEASUREMENT T-027

### **4 ANTI-SOLAR SCIENTIFIC AIRLOCK:**

GEGENSCHEN/ZODIACAL LIGHT S-073  
ATM CONTAMINATION MEASUREMENT T-027  
ULTRAVIOLET PANORAMA S-183

### **5 PROTON SPECTROMETER**

### **6 QCM CONTAMINATION MEASUREMENT**

### **7 RADIO NOISE BURST MONITOR**

## **SSL PARTICIPATION IN SKYLAB EXPERIMENTS**

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## ACKNOWLEDGMENTS

Although the primary purpose for assembling these brief descriptions was to show the involvement by the Space Sciences Laboratory in the Skylab, it became obvious quite early in the preparation that more information was needed than that furnished by the SSL scientists if their work was to be placed in the proper context. Several recent Skylab documents were reviewed, and excerpts have been used to provide background information.

The documents prepared by the Mission Simulation and Requirements Branch, Flight Control Division, NASA Manned Spacecraft Center (MSC) for videotaped briefing listed concisely the scientific objectives in every case, and several of the illustrations in this report were taken from these documents.

Several of the Materials Science/Manufacturing in Space (MS/MS) descriptions are based on material found in the Skylab Experiment Operations Handbook published by the MSC and dated November 19, 1971.

The Apollo Telescope Mount (ATM) portion of this report is in some ways an update of the material found in NASA TN D-5020, Scientific Experiments for the Apollo Telescope Mount, March 1969. Since that report is dedicated to the ATM, it provides a greater in-depth treatment of the subject and should be studied, along with this report, to obtain a fuller discussion of the science.

Various engineering documents provided by the ATM experiment engineers provided helpful background information, as did the report published by the Skylab Program Office, entitled Skylab In-Flight Experiments, dated June 1971.

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## SCIENTIFIC INVOLVEMENT IN SKYLAB BY THE SPACE SCIENCES LABORATORY OF THE MARSHALL SPACE FLIGHT CENTER

### SUMMARY

The Skylab scheduled to be launched in mid-1973 is expected to answer many of the questions that confront the developers of large, permanent space stations. The Skylab experiments can be divided into six categories: medical, technology, operations, science, Apollo Telescope Mount (ATM), and Earth Resources Experiment Packages (EREP). The Space Sciences Laboratory (SSL) of the Marshall Space Flight Center is deeply involved in the areas of technology, science, and the ATM, with a lesser involvement in some of the other areas. This report briefly describes the SSL's role in the Skylab from early feasibility studies through the analysis and publication of flight scientific and technical results.

For the ATM program the SSL is providing a Principal Investigator (PI) and a Co-Investigator for S-056, the X-ray Telescope; a Project Scientist for the ATM, and Experiment Scientists for each experiment. In addition, the SSL is conducting an extensive research effort in optical contamination.

For the Materials Science/Manufacturing in Space (MS/MS) program, the SSL is providing a PI and Co-Scientific Investigators for several of the experiments designed to exploit the unique properties of space.

Experiment Scientists for Skylab Experiments S-073, the Gegendeschein/Zodiacal Light, and S-183, the Ultraviolet Panorama, are being provided by the SSL. A Project Scientist and Project Engineer from the SSL have played vital roles in the development of a proton spectrometer.

Environmental and thermal design criteria, meteoroid protection, and radiation definition and protection are additional areas where the SSL has historically contributed to every major MSFC program. The Skylab involvement is reported herein.

# I. INTRODUCTION

By Carl E. Winkler

For the past several years the SSL has been increasingly active in scientific projects that will culminate in space experiments aboard the Skylab during 1973. The Skylab experiments are logically divided into six categories: medical, technology, operations, science, the ATM, and the EREP. The SSL's major involvement in the Skylab is shown in the frontispiece and is in the areas of technology, science, and the ATM, with a less significant involvement in some of the other areas.

The ATM project was assigned to MSFC in 1966. Briefly, the ATM is a manned solar observatory which can be accurately aimed and is configured of several large instruments designed to make studies and observations of the sun. This takes place from a vantage point above the earth's atmospheric blanket. The various experiments range over the electromagnetic spectrum from the X-ray region to the visible. The SSL has provided a Project Scientist for the overall project and an Experiment Scientist for each ATM experiment. These SSL scientists have become integral members of the various PI teams. They have contributed to the evolution of the experiments through consultation with the PI's, effective interfacing with the scientific community, and in-house scientific investigations. Probably the most outstanding example of the latter is the role the SSL has played in the Optical Contamination Program. Early in the development of the ATM experiments, contamination of these very sophisticated optical systems was recognized as a potentially severe problem. The Project Scientist initiated the first investigations of optical contamination. These early studies revealed that the problem was highly likely to prevent the scientific objectives of the ATM from being met. A many-faceted approach has been developed under the Optical Contamination Program and is fully described in a later section of this report.

Certain data from the ATM experiments, including the MSFC X-ray experiment with the PI from the SSL, will be available to the Skylab Student Project. This is a program in which high school students develop Skylab experiments to be performed by the astronauts. The interest in the high schools has been very gratifying, and the competition for selection has been keen. The approved experiments reflect a great degree of scientific maturity in today's high schools.



Since 1968, space processing experiments have been seriously discussed. Several experiments have now been approved under the overall MS/MS program. The ones in which the SSL is participating are identified in the frontispiece and covered in some detail in another section of this report. During the Apollo Program, starting with Apollo 14, opportunities for so-called "flyback demonstrations" became available. These demonstrations were really some of the first space experiments, and the data obtained have been extremely valuable to the development of the MS/MS Experiments. The SSL scientists and engineers assigned to these Apollo flyback demonstrations have had to prove their ingenuity in order to meet the extremely short time-lines associated with these opportunities (from concept to flight in 6 months). They have been successful in achieving meaningful scientific results, and the experience should prove invaluable to the MS/MS program.

Additional involvement in Skylab includes the development of a proton spectrometer to measure the flux of protons. This measurement is vital because the Skylab orbit periodically intersects a low region of the inner Van Allen radiation belt known as the South Atlantic anomaly, where trapped protons could cause severe degradation of photographic film.

The SSL provides Experiment Scientists to S-073, the Gegenschein/Zodiacal Light Experiment; and to S-183, the Ultraviolet (UV) Panorama Experiment.

Finally, one section of this report contains a discussion of the SSL's involvement in meteoroid and radiation definition and protection and investigations of thermal effects. Historically, the SSL has played a prominent role in the establishment of environmental and thermal design criteria for every major MSFC program. Those contributions peculiar to the Skylab are reported herein.

# MISSION OPERATIONS SUPPORT

By William L. Chisholm

The scientific basis of the Skylab Missions has resulted in a thorough and varied involvement of the SSL. The laboratory's participation has ranged from that of scientific consultation to hardware development and includes both the ATM and Corollary Experiment PI participation. As a natural conclusion to these efforts, the laboratory will provide the appropriate personnel in the Mission Operations Support area to help ensure the scientific integrity of the mission. In particular, the ATM Project Scientist will be in the Flight Operations Management Room (FOMR) at MSC during the mission, and those PI's who are members of the laboratory will be present in either the ATM Science Support Room or the Corollary Experiment Science Support Room during the mission. In addition, the laboratory will be represented in six of the ten Mission Support Groups (MSG), which are the backbone of the Huntsville Operation Support Center (HOSC). Those six are Structural/Mechanical, Electrical Power System, ATM Experiments, Contamination, Corollary Experiments, and Environmental Control/Thermal Control System. Although participation in the Electrical Power System MSG, the Structural/Mechanical MSG, and the Environmental Control/Thermal Control System MSG is largely of a consulting nature, the SSL participation in the ATM Experiments MSG, Contamination MSG, and the Corollary Experiments MSG represents a sizeable and major contribution to these support groups.

Table 1 lists the key Skylab personnel in the SSL and their responsibilities.

TABLE 1. KEY SKYLAB PERSONNEL IN SSL

SSL Personnel	Functions
Dr. James B. Dozier	ATM Project Scientist Radio Noise Burst Monitor
Mr. James E. Milligan	S-056 Principal Investigator
Dr. Anthony C. deLoach	S-056 C0-Investigator MSG S-056
Mr. William C. Snoddy	Space Processing Coordinator
Mr. Hoyt M. Weathers	Contamination Program Manager
Dr. Robert J. Naumann	Contamination Program Scientist
Dr. Thomas A. Parnell	Proton Spectrometer Scientist
Mr. George J. Detko	Proton Spectrometer Engineer MSG Proton Spectrometer
Mr. John W. Watts, Jr.	MSG Proton Spectrometer
Mr. William L. Chisholm	Project Engineer for Mission Operations
Mr. James P. McGuire	S-052 Experiment Scientist MSG S-052, S-056
Mr. Stanley A. Fields	S-054 Experiment Scientist MSG S-054
Mr. John R. Williams	MSG S-056
Mr. Robert M. Wilson	MSG S-056
Mr. Gary M. Arnett	S-082A Experiment Scientist S-082B Experiment Scientist MSG S-082A, S-082B
Mr. Edgar R. Miller	H-alpha Telescope
Mr. Daniel W. Gates	M-552 Scientific Co-Investigator MSG M-415, M-552

TABLE 1. (Concluded)

SSL Personnel	Functions
Mr. Tommy C. Bannister	M-512 Scientific Co-Investigator MSG M-512, M-558
Mr. Mirt C. Davidson	M-512 Scientific Co-Investigator M-555 Scientific Co-Investigator MSG M-512, M-555
Ms. Barbara R. Facemire	M-551 Scientific Co-Investigator MSG M-551
Dr. Eugene W. Urban	M-552 Scientific Co-Investigator MSG M-553
Dr. Lewis L. Lacy	M-566 Scientific Co-Investigator MSG M-566
Dr. Anthony O. Ukanwa	M-558 Principal Investigator
Dr. G. Allen Gary	MSG S-073
Mr. Harry L. Atkins	S-183 Experiment Scientist MSG S-183
Mr. Paul Craven	MSG T-027
Mr. Billy J. Duncan	SGAP Project Manager
Dr. Mona J. Hagyard	SGAP Project Scientist
Mr. James W. Parker	Space Processing g-Calculations

## II. APOLLO TELESCOPE MOUNT (ATM)

By James B. Dozier

In mid-1966 the management of the ATM program was transferred to MSFC. At that time the ATM was to be flown as a detached manned solar physics observatory, utilizing available Command Service Module (CSM) and Lunar Module (LM) hardware to place in earth orbit a group of solar experiments covering spectral regions from 0.2 to 600 nm (2 to 6000 Å). Subsequent changes have resulted in the present Skylab Program, which now includes the ATM in a modified form.

Members of the SSL were encouraged at that time by their director, Dr. Ernst Stuhlinger, to involve themselves in the ATM by aiding ATM PI's in every way possible by applying their scientific expertise in areas of mutual interest while continuing to serve in advisory and problem-solving capacities to MSFC Program Management and to other MSFC laboratories. This involvement has grown through the leadership of Dr. Stuhlinger and his able successor, the late Mr. Gerhard Heller, and is now continuing under the direction of Dr. Walter Haeussermann.

In addition to providing an Experiment Scientist for each experiment, the SSL has appointed a full-time Project Scientist to ensure that the scientific integrity of the program is maintained throughout development, test, and flight. Strong support in radiation measurements, radiation shielding studies, control of radiation damage to film, control of contamination of optical elements and the induced spacecraft environment, radiofrequency and magnetographic observations, and in other areas has been provided. Approximately one-third of the scientists and one-half of the disciplinary areas in the SSL have contributed to the support of the ATM during the past several years. The SSL involvement in the ATM will continue through all three Skylab Missions and through the data evaluation and the publications to follow.

The following sections, all written by direct participants in ATM support, cover some of the scientific research and support activities undertaken by the SSL in behalf of the ATM. Other activities still in the planning and development stages will have to be deferred until a future time.

Table 2 shows the SSL participation in the ATM experiments.

TABLE 2. SSL PARTICIPATION IN ATM EXPERIMENTS

Experiment or Function	Principal Investigator	SSL Role
S-052 White Light Coronagraph	Dr. R. MacQueen, High Altitude Observatory	Mr. J. McGuire, Experiment Scientist
S-054 X-Ray Spectrographic Telescope	Dr. R. Giacconi, American Science & Engineering	Mr. S. Fields and Mr. J. Reynolds, Experiment Scientists
S-055A UV Polychromator/ Spectroheliometer	Dr. L. Goldberg; Dr. E. Reeves, Acting PI, Harvard College Observatory	Mr. E. Klingman, Experiment Scientist
S-056 X-Ray Telescope	Mr. J. Milligan, <sup>a</sup> Marshall Space Flight Center	Dr. A. deLoach, Co-Investigator
S-082A XUV Spectroheliograph	Dr. R. Tousey, Naval Research Laboratory	Mr. G. Arnett, Experiment Scientist
S-082B XUV Spectrograph		Mr. E. Miller, Experiment Scientist
H-alpha Telescope		Dr. J. Dozier, <sup>b</sup> Experiment Scientist
Radio Noise Burst Monitor		Mr. J. Watkins, Experiment Scientist
Real Time Solar Magnetograph (RTSM)		

TABLE 2. (Concluded)

Experiment or Function	Principal Investigator	SSL Role
Skylab Ground-Based Astronomy Program (SGAP)  Solar Flare Video H-alpha Telescope Ground-Based Millimeter Observations  a. Principal Investigator from SSL. b. Also Project Scientist for ATM.		Mr. B. Duncan, Project Manager, Dr. M. Hagyard, Project Scientist  Mr. E. Reichmann, Experiment Scientist  Mr. C. Baugher, Experiment Scientist

# WHITE LIGHT CORONAGRAPH (S-052, HIGH ALTITUDE OBSERVATORY)

By James P. McGuire

Advances in our knowledge of the solar corona have been brought about primarily by advances in observation techniques. The fruitful studies of the corona in X-ray and radio wavelengths are outstanding examples of this premise. These developments, coupled with the perfection of the coronagraph by Lyot in 1930, are responsible for nearly all of our knowledge about the structure of the inner corona. These techniques, productive as they have been, have the serious drawback of revealing only the structure of the innermost corona. Thus many of the most exciting unsolved problems of coronal physics are to be found in the intermediate and outer corona ( $2R < R < 6R$ ). There coronal streamers take on their unique identity, and the coronal gas is accelerated to become the solar wind.

In the past, knowledge of the solar corona has been severely limited by the paucity of observations of the intermediate and outer coronal regions. The many photographs that have been made during the period of totality of solar eclipses represent only a glimpse of a particular coronal configuration, essentially unrelated in time.

Numerous yet unsolved problems have been defined by past research, including

1. What is the three-dimensional structure and form of coronal streamers?
2. What is the correlation between the formation and temporal evolution of streamers and surface features?
3. What is the spatial variation of the solar wind in the corona?
4. What are the optical counterparts of the various coronal radio bursts, and what mechanism triggers them?

## Scientific Objectives

The principal objectives of the White Light Coronagraph Experiment (WLCE) are (1) to obtain synoptic photographic data of the brightness, form, and polarization of the solar corona from 1.5 to 6 solar radii, and (2) to



observe transient coronal phenomena possibly associated with coronal radio bursts.

A secondary objective is to obtain data on other targets of opportunity concerning solar coronal events (eruptive prominences, disappearing filaments, flares, etc.), solar wind and earth-lunar libration (Lagrangian) points.

The SSL furnishes an Experiment Scientist to work with the PI. He has been performing the usual functions of this position to ensure the integrity of the science and has made several valuable contributions by his participation in resolving such questions as

1. What should be the ground-based observation requirements for ATM?
2. What are the scientific reasons for a radio noise burst monitor, and what should be its specifications?
3. What are the contamination problems?
4. Which stellar objects should be used for pointing references?
5. When should S-052 look at the moon and when should it look at the lunar libration points?
6. What are the TV requirements for the S-052 instrument?
7. How and when will the ATM view the 1973 eclipse?
8. What are the film requirements and can they be achieved?
9. What filters should be used on S-052?

## Experiment Description

The equipment for the WLCE comprises an externally occulted coronagraph (Fig. 1); the design is dictated by the need to reduce the instrumentally scattered light to levels on the order of  $10^{-10} B_{\odot}$ , where  $B_{\odot}$  is the mean solar radiance. The optics housing contains the Lyot section of the coronagraph (Fig. 2), the function of which is as follows. Light incident upon the primary

objective,  $O_1$ , is brought to a focus and occulted by an internal disk,  $D_4$ . The infinity focal plane is refocused on the film plane by the Lyot objective,  $O_2$ . Light diffracted by the primary objective aperture is blocked by focusing the aperture outside the aperture of  $O_2$ . This is accomplished by the field lens. The remaining instrumental stray light has its origin in scattering (surface and internal) at the primary objective, and this component is substantially reduced (about  $10^{-4}$ ) through the use of a series of three external occulting disks which shield the primary objective lens from direct sunlight. The stray light incident upon the primary objective is thrice diffracted around the edges of the three external occulting disks.

The external occulting disk assembly and the optics housing are affixed to an optical bench mounted on the ATM spar. The space between the front of the optics housing and the external disk assembly is enclosed in a light-baffle tube, and the experiment camera is located on the side of the optics housing. To prevent thermal imbalance, a heat-dumping mirror on the front of the optics housing forms a low-quality solar image between the external occulting disks and the light tube to reflect solar heat back into space.

To achieve the experiment objectives, the WLCE will photographically monitor the coronal brightness and polarization from 1.5 to 6.0 solar radii from the center of the solar disk at a wavelength band extending from 350 to 700 nm (3500 to 7000 Å). The TV system utilizes a low-light-level camera at the image plane and presents a coronal image to the observer at the monitor; the TV image will be only 4.5 solar diameters.

The spatial resolution of the diffraction-limited optics is 4 arc sec, the film can resolve 8 arc sec, and the resolution capability of the TV is 30 arc sec.

An elevation and azimuth pointing stability of  $\pm 5$  arc sec for 16 min and a roll stability of 0.5 arc min for 1 min are required.

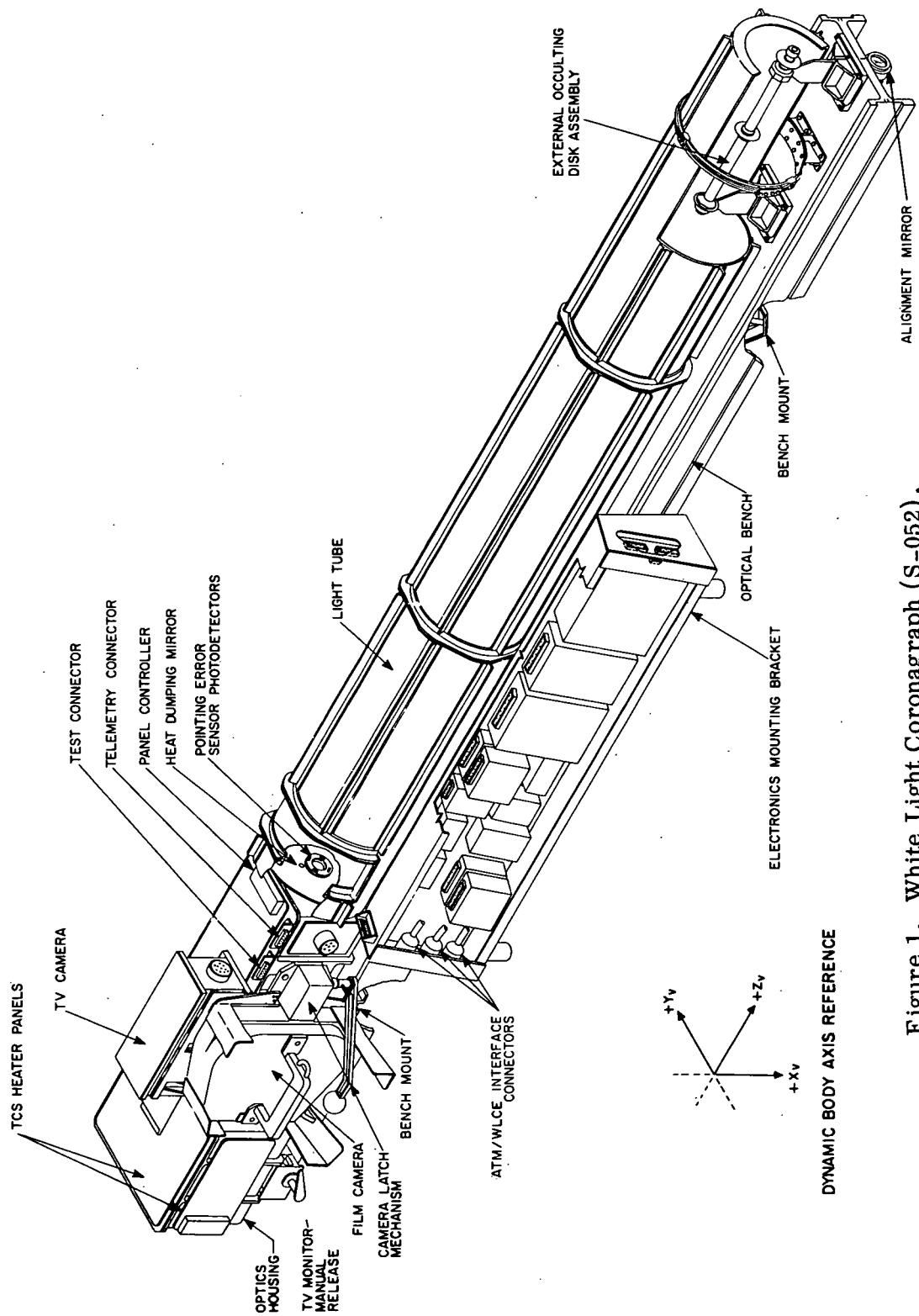


Figure 1. White Light Coronagraph (S-052).

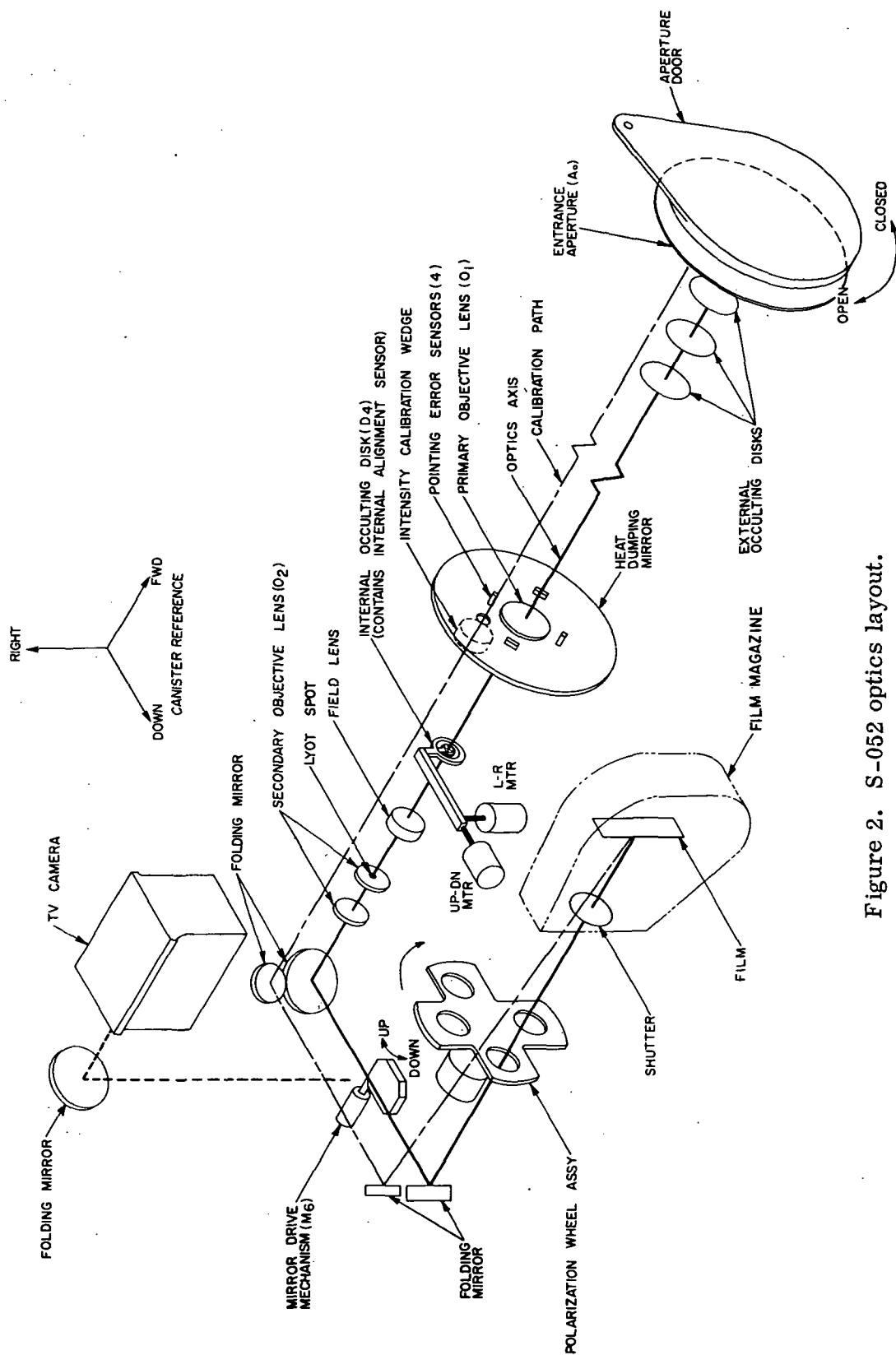


Figure 2. S-052 optics layout.

# X-RAY SPECTROGRAPHIC TELESCOPE (S-054, AMERICAN SCIENCE AND ENGINEERING)

By Stanley A. Fields and John M. Reynolds

The ATM experiment S-054 consists of an X-ray Spectrographic Telescope to study the soft X-ray emission of the sun during solar flares. The primary instrument consists of a grazing incidence telescope, a grating for spectral information, a filter wheel to vary the wavelength response, and a camera utilizing 70-mm format film to record the image (Fig. 3).

A small telescope is used to focus an image onto a scintillator crystal which is in contact with the fiber optic faceplate and photocathode of the image dissector tube. The image dissector provides positional information on solar flare activity. The presence of an intense target on the cathode-ray tube allows the astronaut to boresight the optical axis of the S-054 telescope to the region of activity.

## Scientific Objectives

The primary purpose of the American Science and Engineering (AS&E)/ATM Experiment S-054 is to study solar emission in the soft X-ray spectrum with a spectral resolution of a fraction of a nanometer, a spatial resolution of 2 arc sec, and a temporal resolution of 1 sec. The experiment will make it possible to obtain high-resolution spectroheliograms. Information will be obtained in the soft X-ray region that will aid in determining the spectral distribution in flare emissions, as well as the temporal evolution (from a fraction of a second to many seconds), of various features in the makeup of the solar corona. The photographic records obtained will permit measurements to be made to distinguish thermal from nonthermal sources of X-ray emissions associated with solar flares and to evaluate the various postulated acceleration mechanisms.

In particular, the S-054 instrument is designed to achieve the following objectives:

1. Obtain images of X-ray flare events with a spatial resolution of a few seconds of arc.

2. Simultaneously record flare spectra over the range of 0.2 to 6 nm (2 to 60 Å) with a spectral resolution of a fraction of a nanometer and detect the presence of lines (or groups of lines) and/or the continuous spectrum.

3. Follow the evolution of the spatial image and spectral distribution during the onset, development, and decay of a flare with a time resolution of approximately 1 sec.

4. Correlate these measurements with the ground-based radio and H- $\alpha$  measurements for the purpose of constructing a comprehensive picture of solar flare phenomena.

5. Perform similar measurements during nonflare conditions, study the active solar region, determine the relation between centers of activity and flare events, and study the general coronal emission.

6. If feasible, perform a limited number of observations of celestial X-ray sources within a few degrees of the solar disk.

## Experiment Description

The primary assembly of the S-054 experiment will be a telescope assembly (Fig. 3) consisting of a soft X-ray transmission grating, an image-forming soft X-ray telescope, and a film camera. The transmission grating will be positioned in the optical path to disperse a portion of the incident radiation. The undispersed image and the dispersed X-ray spectra will be focused at the film plane of the camera where they will be recorded on 70-mm film. A visible light lens will record an image of the solar disk on the film.

While the prime objective is to make observations of solar flares with high spectral and spatial resolution, the experiment design will also provide for examining nonflare conditions by using appropriate filters mounted in a filter-wheel assembly. These filters may be substituted for a grating as commanded by the astronaut. This will provide the capability, during non-flare conditions, for producing broadband X-ray photographs of the sun in selected regions of the X-ray spectrum. A subsidiary electronic imaging system will provide positional information on solar flare activity that will allow boresighting the optical axis of the AS&E telescope to the region of activity on the solar disk.

## SSL Contribution

In addition to furnishing the PI with an Experiment Scientist, the SSL has pursued in-house X-ray investigations in support of S-054 and other approved X-ray experiments.

A precision vacuum X-ray reflectometer has been designed and built to study the basic properties of candidate materials for X-ray telescopes. Measurements are made to determine the effects of surface finish, polishing techniques, material, and contamination on the total reflection of X rays by optical flats. Measurements are also conducted to determine the scatter properties of an X-ray beam reflected by the optical flats.

A schematic of the instrument used to make these measurements is shown in Figure 4. The system consists of an X-ray source, a monochromating crystal, a sample holder, two detectors, and adjustable slits to define the X-ray beam. The X-ray source is designed so that the anode can be changed to select various lines between 0.15 and 11.3 nm (1.5 Å and 113 Å). The crystal and sample mounts are designed so that the angle of incidence,  $\theta$ , can be set remotely and measured to arc-second accuracy. The reflectometer operates inside an oil-free vacuum chamber at  $10^{-5}$  N/m<sup>2</sup>; the slit adjustments, detector motion, sample selection, and angular adjustments of the crystal and sample are made by remote control.

Following the thermal-vacuum testing of the flight optics in the MSC Chamber A, two optical flats were measured at 0.834 nm (8.34 Å) to determine the effects of possible contamination. The samples measured were (1) S33E, quartz, and (2) E6-12, quartz coated with platinum. The measurements consisted of defining the total reflectivity curve and measuring the scatter curve at  $\theta = 50$  arc min. Since these samples had not been measured before their exposure, two control samples were measured. The samples from Chamber A showed a decrease in reflection efficiency when compared with their control sample. However, this decrease was small and since the samples had not been premeasured, no definite conclusions could be drawn about the contamination effect. The angular width at half maximum of the scattered X-ray beam was compared with the direct beam and found to agree.

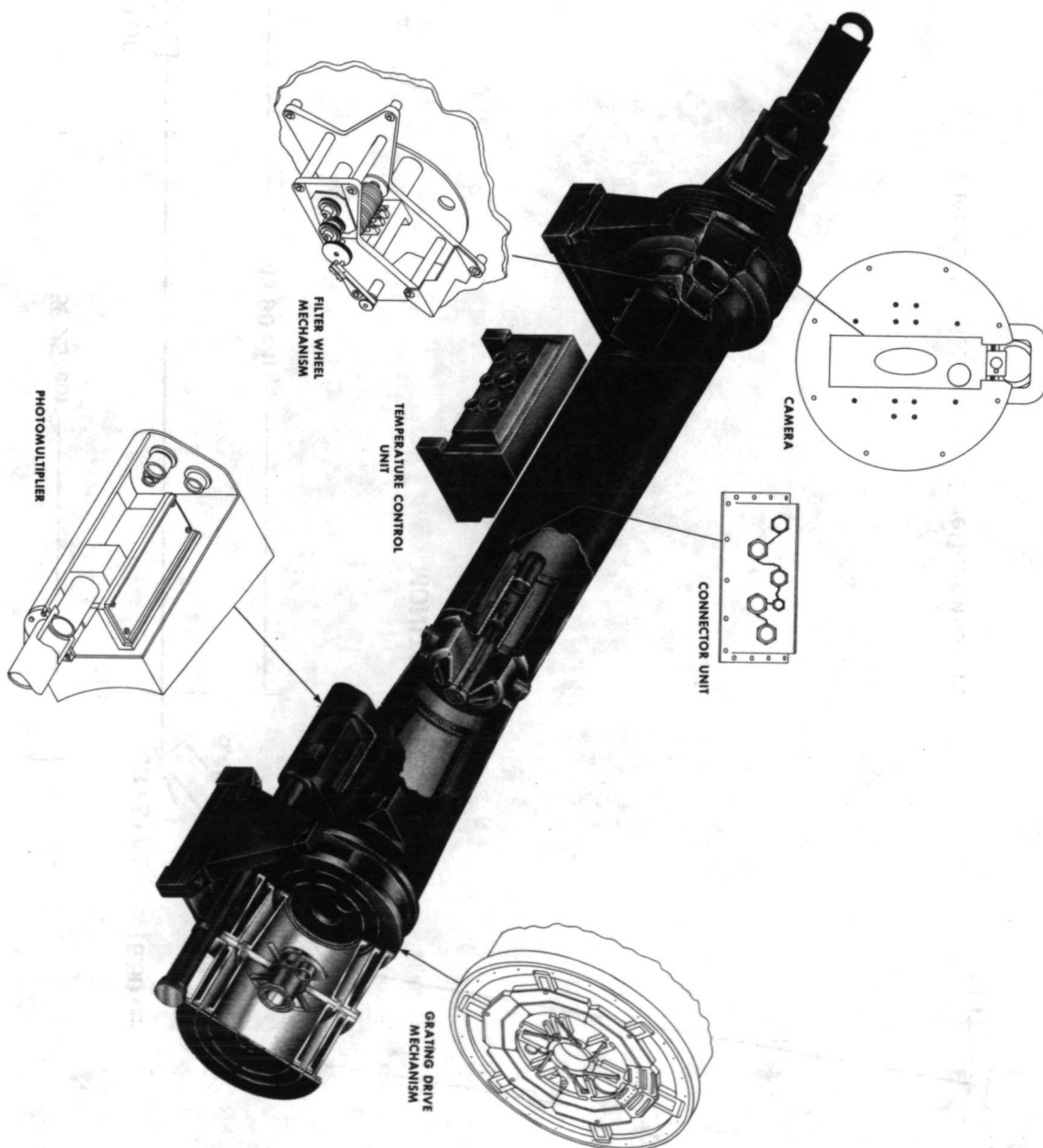
Two fused silica optical flats were measured at 0.834 nm (8.34 Å) and inserted in the ATM when the E6-12 sample was removed. These samples will be removed before launch and remeasured.

In addition to the aforementioned measurements and in support of the ATM as well as other programs, measurements are being made to determine the effect of dust particles on the performance of optical flats at 0.834 nm (8.34 Å).

An analytical program is under way so that the experimental results may be interpreted in the light of their possible impact on X-ray telescope performance. Mathematical equations necessary to understand the effect of the above parameters are being derived and programmed to assist in analyzing the X-ray reflectometer data.



Figure 3. S-054 telescope assembly.



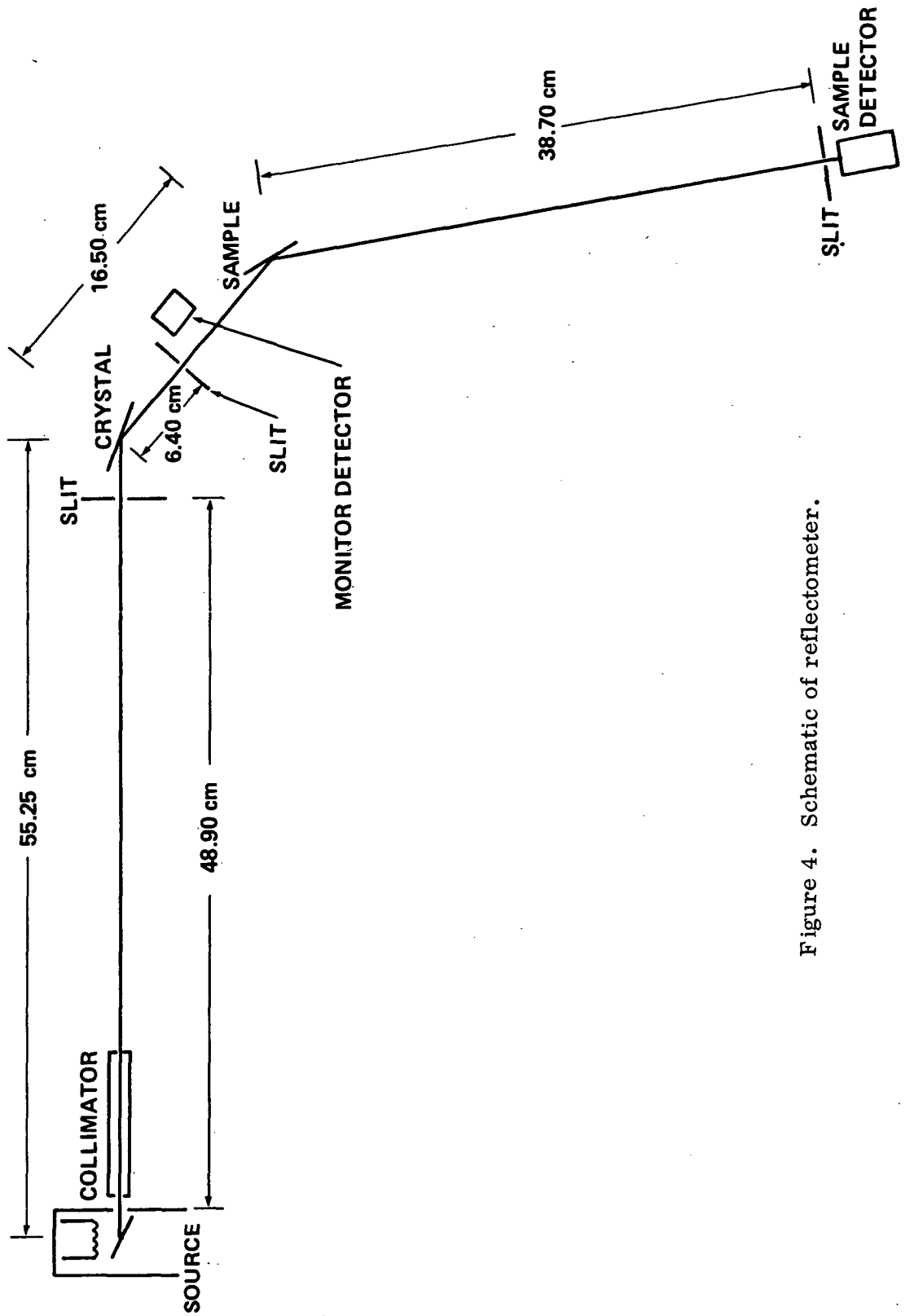


Figure 4. Schematic of reflectometer.

# UV SCANNING POLYCHROMATOR/SPECTROHELIOMETER (S-055A, HARVARD COLLEGE OBSERVATORY)

By Edwin E. Klingman

The Harvard College Observatory (HCO) experiment to be flown on the ATM consists of a short wavelength spectroheliometer to take intensity measurements of the sun in the ultraviolet spectrum. The S-055A instrument operates in the 30- to 135-nm (300- to 1350-Å) (temperatures  $\sim 10\,000^\circ\text{K}$  to  $\sim 1\,400\,000^\circ\text{K}$ ) region with a 5-arc-sec spatial resolution and a spectral resolution of about 0.13 nm (1.3 Å). The acting PI for this experiment is Dr. E. Reeves of the HCO.

The data returned from this experiment will give information about the structure and processes taking place in both the active and quiet regions of the solar chromosphere and solar atmosphere.

The instrument operates photoelectrically and requires no film or extravehicular activity (EVA) on the part of the astronaut. Thus, operation between manned visits to the Skylab is possible.

Early in the ATM program the SSL Experiment Scientist participated on the PI team to become thoroughly familiar with the scientific objectives and techniques to be used. He worked closely with the experiment engineer in a scientific advisory capacity.

A major contribution to S-055A by the SSL was a contamination analysis of the experiment packages using Monte Carlo computer methods. Also, sticking coefficients of known materials in known geometries on critical surfaces of the experiment were determined through laboratory investigations.

# X-RAY TELESCOPE (S-056, MARSHALL SPACE FLIGHT CENTER)

By Anthony C. deLoach

The S-056 X-Ray Telescope is the sole NASA in-house experiment in the ATM. The PI is James E. Milligan of the SSL. Co-Investigators are James H. Underwood of the Aerospace Corporation and Anthony C. deLoach of the SSL.

Considerable information regarding the physical state of the solar corona can be obtained from observations in the soft X-ray region. These data will help to give a better understanding of mass and energy transfer mechanisms and of the initiation and temporal development of solar flares. Within the 0.5- to 3.3-nm (5- to 33-Å) wavelength region, the instrument will obtain spatial and temporal distributions of X-ray sources over the solar disk and beyond the limb to approximately 1.5 solar radii.

The X-ray emission from the sun can be conveniently divided into three principal components: (1) emission from the quiet corona at times of no solar activity or from undisturbed areas distant from active regions, (2) a slowly varying component from active regions in the corona above phenomena such as sunspots and plages, and (3) rapidly varying X-ray bursts which may or may not be associated with solar flares, eruptive prominences, or radio bursts. Within each of these categories, several problems of interest in modern solar physics are proposed for investigations and are listed as follows:

## 1. Quiet Sun Emission

- a. Electron density and temperature in regions far from active centers.
- b. Relationship of the quiet sun emission with solar magnetic field as evidenced by polar darkening and the appearance of X-ray filaments, plumes, and arches.

## 2. Active Region X Rays

- a. The size, shape, electron density, and temperature of X-ray emission associated with active regions. Correlation with visible light spectroheliograms, white light, ultraviolet coronagraph data, and magnetic data.

b. Variation of the size and height of the coronal emission with excitation energy of the radiation observed.

### 3. Rapidly Varying Bursts

a. The processes occurring during the initial stages of flare development. The relationship between flare development in the X-ray, H- $\alpha$ , and radio regions.

b. The correlation between the importance of a flare and the X-ray burst intensity.

c. Temporal and spectral correlations between X-ray bursts originating from flare versus nonflare sources.

d. The role of local magnetic field strengths and gradients in triggering and sustaining flare development.

The spatial information required to satisfy the scientific objectives will be in the form of filtergrams, utilizing a grazing incidence paraboloidal/hyperboloidal mirror system, several metal and plastic bandpass filters, and X-ray-sensitive film. Supplementing the solar images, the spectral distribution of the X-ray flux between 0.2 and 2 nm (2 and 20 Å) will be provided by two proportional counters, the pulses from which are input to and sorted by pulse-height analyzers.

## Experiment Description

This section defines the scientific need and methods for the S-056 Extreme Ultraviolet X-Ray Telescope Experiment.

The purpose of this experiment is to gather data which will contribute to a better understanding of the physical processes occurring in the solar atmosphere, with the primary emphasis placed on transient solar events such as solar flares. Thus far a significant quantity of data has been obtained on the time dependence of the spectrum of solar flares (and other transient phenomena) from the X-ray region out to the radio region. However, data on the structural changes of the emitting regions in the ultraviolet and X-ray regions are nonexistent because of limitations of the various observing techniques previously available.

This experiment will provide crude spectral data using proportional counters and pulse-height analyzers and spatial data in the form of X-ray filtergrams (solar images of narrow wavelength intervals). The spectral data will be analyzed to give flare temperatures, densities, and chemical abundances. The filtergrams will indicate both the temporal and spatial variations of these quantities in the flare region.

The strong nonthermal X-ray emission characteristics of flares will be used to gain a better understanding of the plasma instabilities and their influence on flare development. This understanding should lead to more definite relationships between sunspots and flare formation. Of particular interest will be the processes occurring during the initial stages of flare development and the relationship between flare development in the X-ray, H- $\alpha$ , and radio regions.

The spatial information required to satisfy the objectives can be obtained with a grazing-incidence telescope system and the spectral information with proportional counters (Fig. 5), particularly for events of limited spatial extent.

Gas-filled proportional counters are used to measure the spectral distribution of transient solar events in the X-ray region. Metallic windows on the counters provide a basic passband for X-ray photons, restricted by both a high and a low energy limit.

Proportional counters have the property of responding with output pulses which are linearly proportional to the energy of the detected photons. An analysis of the output pulses on an amplitude basis provides a satisfactory method of photon energy resolution. The process of sorting the pulses (in pulse-height analyzers) is performed with high-speed digital circuitry, and, therefore, the speed of response of the proportional counters is not appreciably decreased.

Two limitations of proportional counters should also be identified. One is that the energy resolution is limited to no more than 15 percent ( $\Delta E/E \gtrsim 0.15$ ); the other is that the characteristics of proportional counters change after a high but limited number (about one billion,  $10^9$ ) of photons has been detected.

Soft X-ray solar images are formed using a two-element, double-reflection aplanatic telescope (Fig. 6). Paraboloidal and hyperboloidal elements placed confocally to each other, and used in regions where their

surfaces are nearly parallel to their axis of revolution, form surfaces that are at high angles of incidence to the incoming solar photons. The properties of such a combination are that incoming paraxial rays first strike the paraboloidal surface, undergo total external reflection, and are imaged toward the focal point. Before focusing, the rays strike the confocally placed hyperboloidal surface, where they again undergo total external reflection and are imaged at the hyperboloid's second focal point.

The camera's film plane is placed coincident with this second focal point, and six different filters are positioned ahead of the film plane. The filter characteristics are shown in Table 3. The resulting data are solar filtergrams in the 0.5- to 3.3-nm (5- to 33-Å) region.

It is to be noted that the image quality of this focusing device is excellent on the optical axis and is slightly degraded with small angular deviations from the optical axis.

## Operational Modes

The telescope may be operated in any of several operational modes, which are selected by the astronaut as dictated by solar conditions and/or a preselected observational program. The characteristics of these modes are shown in Table 4.

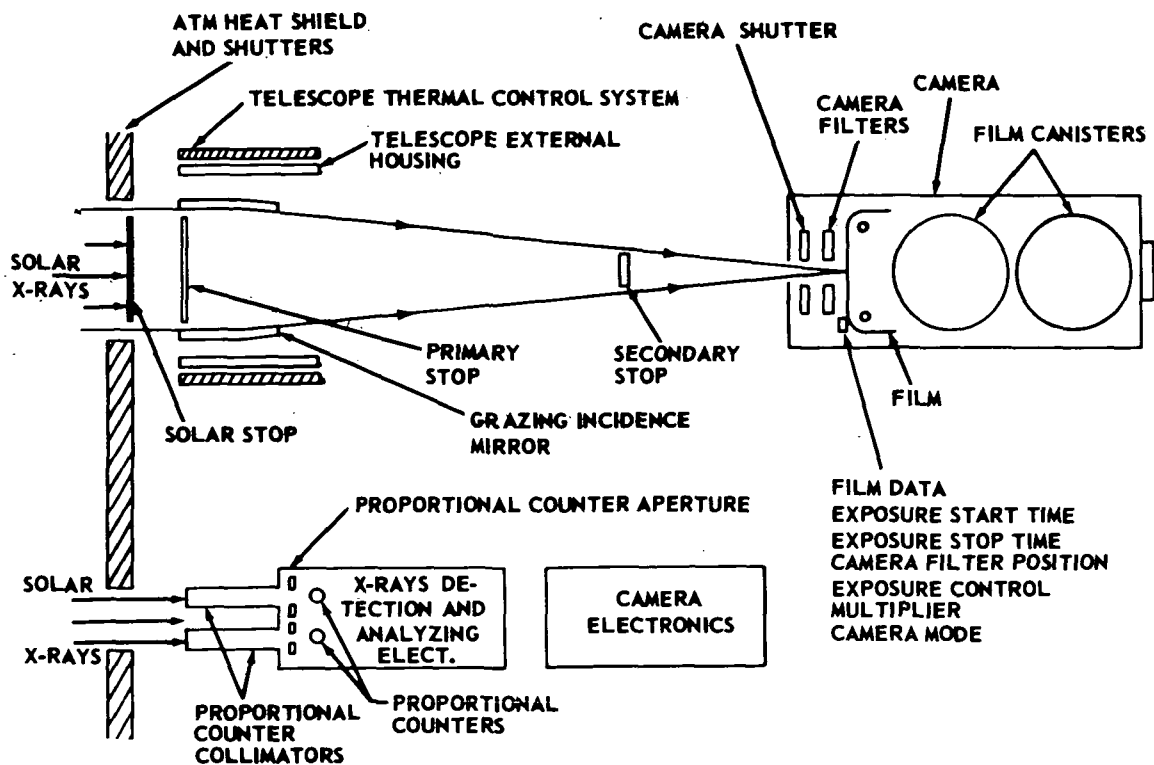


Figure 5. Block diagram of MSFC X-Ray Telescope (S-056).

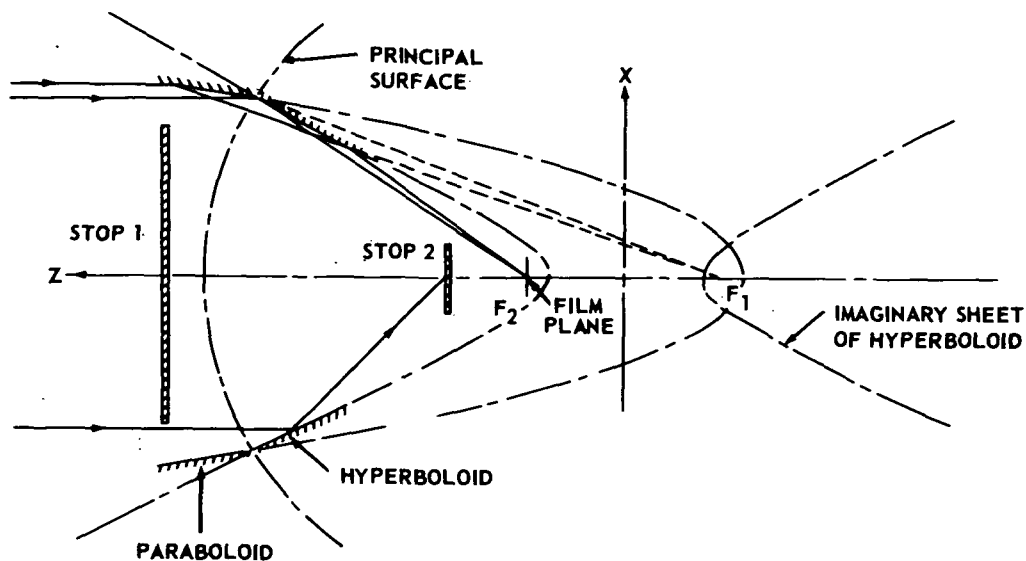


Figure 6. Two-element, double-reflection aplanatic telescope.



TABLE 3. S-056 FILTER CHARACTERISTICS

Filter Position	Material	Nominal Exposure Time <sup>a</sup> (sec)		Thickness (cm)	Bandpass (nm)
		Single Frame	Active/Auto		
1	Aluminum	90	5	0.001270	0.5 to 0.8, 0.8 to 1.8
2	Aluminum	30	—	0.000635	0.5 to 0.8, 0.8 to 2
3	Titanium	50	5	0.00021844	0.5 to 1.2, 2.7 to 3.3
4	Beryllium	60	—	0.00254	0.5 to 1.2
5	Beryllium	60	5	0.00762	0.5 to 1.1
6	Multilayer Dielectric Neutral Density with Inconel Overcoat	1	—	0.3175	632.8 ± 4

a. Exposure times may be multiplied or divided by 3.2 by crewman.

TABLE 4. S-056 OPERATIONAL MODES

Mode	Characteristics
Single Frame	Desired filter is manually selected; single photograph taken.
Patrol	One photograph taken at each of the six filter positions.
Active I	Rapid photographs taken through filters 1, 3, and 5. Sequencing continues for 5 min.
Active II	As in Active I, except one sequence of three photographs is taken per minute for 20 min.
Active III	As in Active I, except one sequence of three photographs is taken per 10 min for 60 min.
Auto	Camera automatically sequences through Active I, Active II, and Active III.

# XUV SPECTROHELIOGRAPH (S-082A) AND SPECTROGRAPH AND XUV MONITOR (S-082B) (NAVAL RESEARCH LABORATORY)

By Gary M. Arnett

The Naval Research Laboratory (NRL) is contributing two experiment packages to the ATM. The PI for both is Dr. R. Tousey. The two packages consist of an Extreme-Ultraviolet (XUV) Coronal Spectroheliograph (S-082A) and a Spectrograph and XUV Monitor (S-082B). The scientific objectives of these packages will be discussed separately.

## XUV Spectroheliograph (S-082A)

The scientific objective of the S-082A is to photographically record XUV images of the solar disk and corona to 1.5 solar radii. The spectral range will be 15 to 62.5 nm (150 Å to 625 Å) in two bands (15 to 33.5 nm and 32.1 to 62.5 nm). The spectral resolution is to be 0.013 nm (0.13 Å) for 10 arc sec, and the spatial resolution is to be 5 arc sec.

## Spectrograph and XUV Monitor (S-082B)

The scientific objectives of the S-082B are (1) to photographically record line spectra of the solar chromosphere and part of the transition region in the spectral range 97 to 394 nm (970 Å to 3940 Å) and (2) to provide a real-time video presentation of the solar disk and corona to two solar radii in the spectral range 17 to 55 nm (170 Å to 550 Å).

The spectrograph will record spectra from areas measuring  $2 \times 60$  arc sec on the solar disk and out into the chromosphere and corona with an effective spatial resolution of about 4 arc sec perpendicular to the slit. The total spectral range will be covered by separate exposures in two spectral sections, 97 to 197 nm (970 Å to 1970 Å) with 0.004 nm (0.04 Å) spectral resolution and 194 to 394 nm (1940 Å to 3940 Å) with 0.008 nm (0.08 Å) spectral resolution. The spatial resolution is about 3 arc sec.

The XUV monitor will assist the astronaut in deciding which emitting regions of the sun should be photographed. It is also expected to show solar flares and flare precursors not visible in H-alpha. This will enable him to correct the pointing and to decide when to begin operating the S-082B and other ATM instruments in the flare mode. After transmissions to the ground, the XUV pictures will provide valuable information to the PI on this extremely important area of the solar spectrum in greater detail than has been obtained to date.

The observations of both the spectrograph and the XUV monitor will cover periods of greater and lesser activity during two rotations of the sun and will record the temporal changes of centers of activity and of flares.

## SSL Involvement in S-082A/S-082B

The SSL has been involved in both direct and indirect studies supporting these experiments. The major involvements are outlined as follows.

Experiment Scientist. Although the activity of the Experiment Scientist was of prime importance in the early stages of the ATM, the author is continuing to serve this function at the present time. The initial contribution of this function was to serve as the primary scientific contact to the PI, Dr. R. Tousey. It was through this contact that many of the scientific requirements were conveyed to the engineering community and, also, that the contamination problem was uncovered and treated in a preventive manner. Through the development process of the ATM and Skylab, this contact has continued, and numerous potential problem areas have been studied. A few of these are outlined below.

Grating Efficiency Deterioration. In 1971, in support of S-082B, the Space Thermophysics Division of the SSL participated in an analysis of the flight experiment pertaining to a substantial deterioration of instrument efficiency. Dr. J. Cowan, resident research associate, and Mr. J. Zwiener were the principal participants. This loss in efficiency was finally traced to a deterioration of the instrument's main grating. Dr. Cowan tested this grating to determine if contamination was the cause of the problem. Also, Dr. P. Peters of the SSL's Nuclear and Plasma Physics Division conducted studies on sections of the grating in attempts to find contamination. It was found that the grating was not significantly contaminated and that another mechanism was at fault. The NRL concluded that the degrading was caused

by intermetallic diffusion of the aluminum coating on top of the gold layer on the grating. Further tests at the NRL, Goddard Space Flight Center (GSFC), and MSFC substantiated this conclusion. Gratings without the gold underlayer were used to replace the deteriorated gratings.

**Thin-Film XUV Filter Studies.** A study contract has been let to The Boeing Company to evaluate transmission enhancement of thin-film aluminum filters similar to those being used by the NRL on its ATM flight experiment. The study is an extension of a contract to determine the feasibility of an active cleaning technique. This effort is significant in that if sufficient increases in filter transmission in the XUV wavelength region can be achieved, the overall efficiency of the NRL's flight experiment would be improved.

Preliminary results have been very good, indicating up to a 50 percent increase of the original transmission value. Additional studies are required to determine if structural degradation problems occur during the process.

**Hard-Vacuum Test of ATM Photographic Film.** In 1969 James Zwiener of the Space Thermophysics Division of the SSL ran a series of tests to determine the effect of prolonged exposure of ATM photographic film to a hard vacuum ( $10^{-7}$  torr range). These tests were performed in collaboration with the NRL.

Utilizing results of these tests along with results from additional tests at the NRL, Winter and Van Hoosier published a report (NRL Report No. 7072) in 1970 indicating that Kodak 104-01 film is the best available film for the NRL-ATM Skylab mission.

# HYDROGEN-ALPHA TELESCOPE

By Edgar R. Miller

The prime function of the ATM Hydrogen-Alpha (H-alpha) Telescope is to provide the astronaut with a television display of the sun's chromosphere as well as sunspots within the photosphere. Such a display allows the astronaut to identify quiet, active, and flaring regions upon the sun. The H-alpha telescope has been called the "eyes of the ATM." Since H-alpha is considered so important to the ATM mission, the Harvard College Observatory's H-alpha telescope is also fitted with a vidicon television, in addition to its 35-mm film camera, to help assure a working system.

The telescope (Fig. 7) is a 16.5-cm (6.5-in.) aperture, f/30 Cassegrainian type with telecentric corrector lenses, an H-alpha filter, and a vidicon television camera detector.

Heat rejection is accomplished by a full aperture filter on the front of the telescope, which transmits a band of about 30 nm (300 Å) approximately centered on H-alpha. The filter reflects most of the remaining solar energy, thereby absorbing only a small percentage. A zoom relay lens allows fields of view over the range of 7 arc min to 35 arc min. With the 7-arc-min field of view, the system resolution is about 1.5 arc sec, allowing detailed inspections of active regions. With the larger fields of view, areas up to slightly larger than the solar disk can be viewed, with corresponding losses in resolution.

The H-alpha filter is comprised of a solid Fabry-Perot etalon of fused silica, a multilayer interference blocking filter, which limits the band-pass to the proper fringe, and a temperature-controlled oven, which contains the etalon and blocking filter and is preset to a temperature that permits transmission of H-alpha light. Since the temperature coefficients are different [0.1-nm (1-Å) shift per 45°C for the Fabry-Perot and 0.1-nm (1-Å) shift per 15°C for the blocking filter], the two elements must be carefully matched so that the overall filter performance is optimized at the desired operating temperature. Figure 8 shows the system spectral response for the telescope.

The SSL's role in the development of the telescope was to provide technical assistance to the Project Engineer. Since the SSL is also working with H-alpha telescopes and filters in its own solar physics program, this assignment assured maximum communication of mutual problems. The SSL

participated in meetings and discussions and in testing of the telescopes during the various stages of development and also provided its heliostat for functional checkout of the ATM H-alpha prototype telescope upon its delivery from the manufacturer.

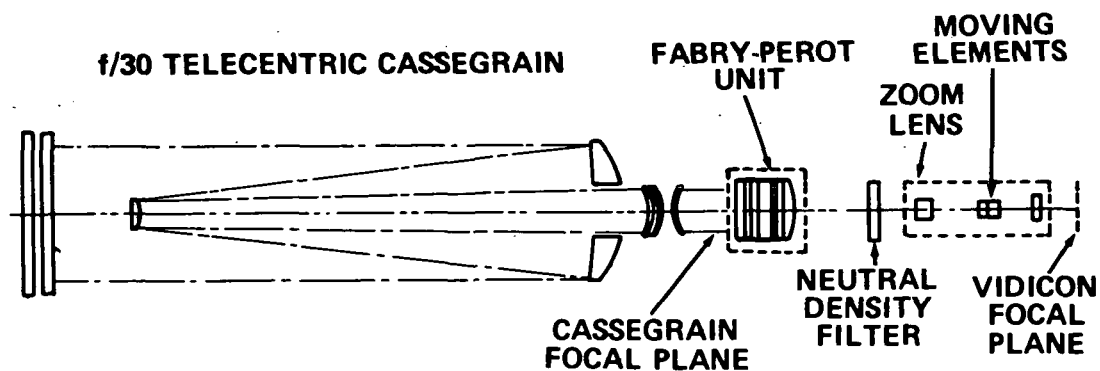


Figure 7. Optical schematic of ATM Hydrogen-Alpha Telescope.

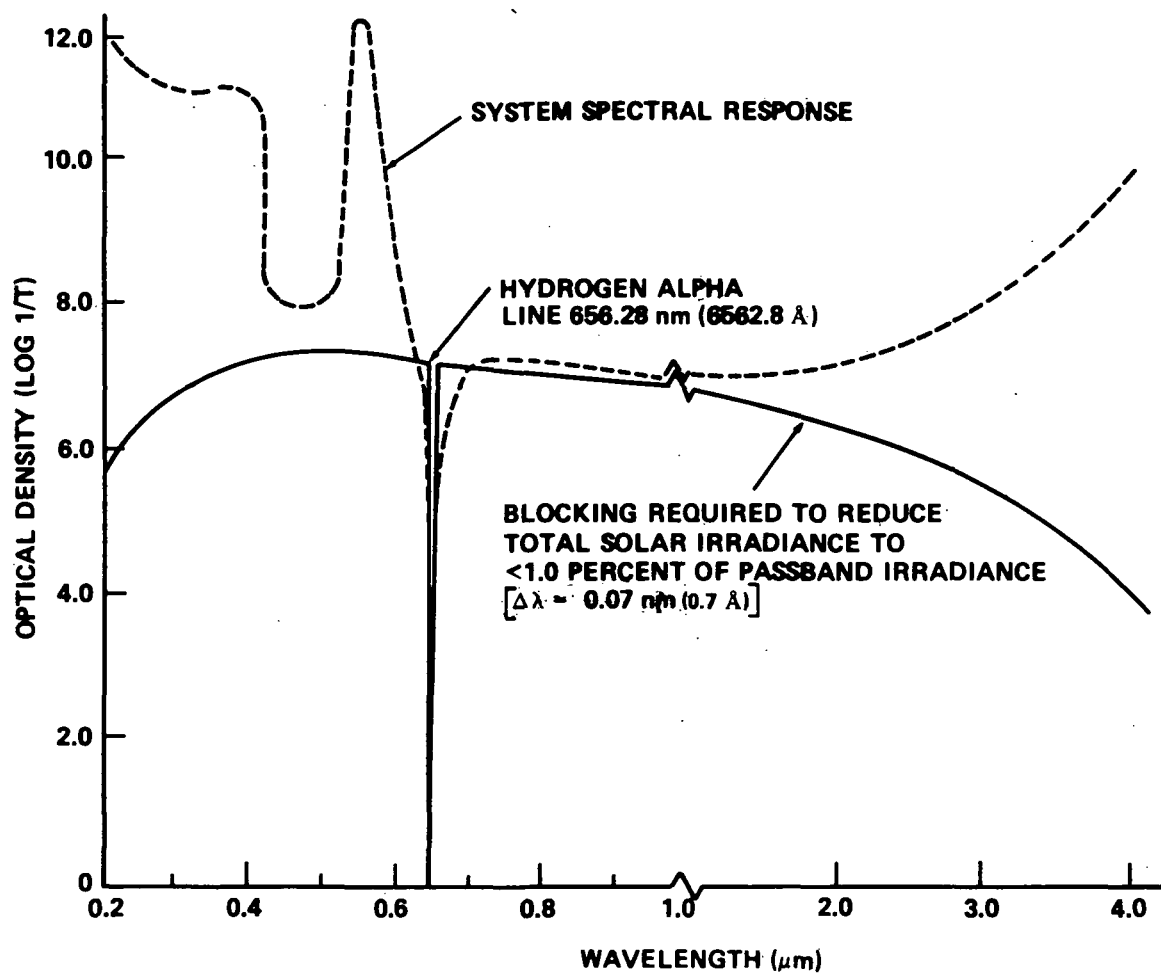


Figure 8. Hydrogen-Alpha Telescope system spectral response.



# RADIO NOISE BURST MONITOR

By James B. Dozier

An extremely valuable part of the data to be gathered by the ATM experiments will be that generated during the onset of flares. Without warning before the onset of a flare, a patrol mode of operation which rapidly uses scarce supplies of film would be required. Recent solar radio observations have indicated that solar flares have radiofrequency precursors in both the millimeter and centimeter regions of the solar radio spectrum that can provide a means of preflare-onset alerts. A Radio Noise Burst Monitor (RNBM) designed to operate in the reserved radio-astronomy frequency band at 4.990 to 5.000 GHz has, therefore, been made a part of the ATM system to serve as an onboard quick reaction monitor of solar flare activity to permit immediate manual activation of the other solar experiments.

The RNBM is a small radio telescope utilizing traditional, well-proven radio-astronomical instrumental techniques. The required sensitivity and dynamic range resulted in the design of a gain-modulated switched radiometer employing a tunnel-diode preamplifier. A calibrated noise source is used to permit absolute flux/temperature calibration at two points in the instrument range.

The 10-MHz bandwidth and the 4-sec integration time chosen and the required sensitivity of 5 to 10 solar flux units led to the use of a 0.62-m (2-ft) parabolic antenna. This antenna is fixed to the spacecraft as shown in the frontispiece of this report; its axis is parallel to the ATM boresight axis and is therefore pointed at the sun when the ATM is solar-oriented. The RNBM output is simultaneously displayed visually on a panel meter on the instrument and plotted by the ATM Activity History Recorder, giving the astronaut a visual indication of the solar radioactivity level within about 10 sec of the arrival of the signal at the spacecraft. A manually settable threshold monitor circuit is capable of activating an alert light on the RNBM panel and, at the astronaut's discretion, may be used to activate the spacecraft visual and audible alarm system.

# REAL TIME SOLAR MAGNETOGRAPH (RTSM)<sup>1</sup>

By J. R. Watkins

The scientific objective of the Real Time Solar Magnetograph (RTSM) is to support the ATM by studying the physics of the solar atmosphere to further refine theoretical models. The solar magnetograph is a joint project of the NRL and MSFC. Preparatory experimental and theoretical work is being done to acquire and analyze data as background for an analysis of the S-056 ATM experiment science data. During the Skylab mission, a network of ground-based solar observatories will send solar activity data to the ATM PI's at the MSC. The SSL will operate the RTSM facility and make coordinated observations of solar activity to provide data in the same manner as the other observatories.

The RTSM is representative of magnetograph systems which use a narrow-band birefringent filter plus an assembly of polarizing optics to uniquely determine the state of polarization of a narrow wavelength interval of the light emerging from a small element of the sun's surface. The specific problems to which the RTSM is addressed are (1) to establish the relationship between measured polarization and solar magnetic fields, and (2) to correlate measured magnetic field distributions with distributions calculated theoretically from various assumptions concerning the solar plasma. In regard to the first problem, calibration is approached by solving the radiative transfer equations for the line profiles of the Stokes parameters and computing the percentage of linear and circular polarization across the line profile. Correspondingly, if it is assumed that the polarization of the light is caused solely by the presence of a homogeneous magnetic field in the process of formation of the absorption line in the relevant layers of the sun's atmosphere, this magnetic field can be determined both in magnitude and direction from measurements of the degrees of linear and circular polarization of the light transmitted by the narrow-band filter. In connection with the second problem, the shock calculation for infalling prominence material in the infall-impact model of a solar flare yields appropriate conditions for H-alpha emission. As an extension of the infall-impact theory, a theoretical model for type II and type IV solar radio

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1. Excerpted from Real Time Solar Magnetograph (First Generation) by M. J. Hagyard, E. J. Reichmann, N. P. Cumings, W. C. Snoddy, and J. R. Watkins, MISC-SSL-70-5, edited by J. R. Watkins, December 1970.

burst has been developed and numerical calculations are in progress. Other investigations in this regard include the compressible and the incompressible magnetohydrodynamic (MHD) models of an isolated sunspot with poloidal and perturbed force-free magnetic fields, respectively.

The RTSM solar observing site is located at Building 4347 at the MSFC. The dome (built by Observa-Dome) which houses the telescopes that are used at the observing site is on top of a 12.8-m (42-ft) tower, which is a modified test stand. A 30.48-cm (12-in.) Ealing-Competition Associates f/13 Cassegrainian telescope, a 12.7-cm (5-in.) Spectrolab H-alpha telescope, and a Spectrolab 5.08-cm (2-in.) solar tracking telescope are coaligned and fastened to the top of a concrete pier. The pier allows the 30.48-cm (12-in.) telescope to view approximately 150 deg of the celestial hemisphere.

The 30.48-cm (12-in.) Cassegrainian telescope collects light for the RTSM optics, Zeiss filter, and secondary electron conduction (SEC) vidicon detector. The Zeiss filter is a specially built birefringent filter designed to have a bandpass of about 0.01 nm (0.125 Å) at the 525.02-nm (5250.2-Å) iron line wavelength. The optical characteristics of the filter were experimentally verified at Kitt Peak National Observatory, using the McMath solar telescope and associated spectrometer. Light first passes through a prefilter with a half-width of 21 nm (210 Å) centered at 525.02 nm (5250.2 Å) and attached to the front of the telescope. The filter attenuates the solar energy arriving at the Cassegrainian optics. The peak transmission of the prefilter at 525.02 nm (5250.2 Å) is 65 percent; therefore, approximately 10 percent of the solar energy is transmitted. For a more detailed description of the NRL optics box, optical train, Zeiss filter, and electronics, see the document referenced in footnote 1.

Magnetograph measurements are made by using polarizing optics consisting of two  $\lambda/4$  plates, two KD\*P crystals, and a linear polarizer. The analysis of the polarized light is accomplished with six combinations of these elements, with the retardance of the KD\*P crystals being electrically controlled by varying the plate voltage. The effect of each of these six combinations on a beam of partially polarized light can be described in terms of the Stokes parameters and the Mueller calculus. The Stokes parameters  $I_\lambda$ ,  $Q_\lambda$ ,  $U_\lambda$ , and  $V_\lambda$  are the four components of a mathematical vector which completely describes the intensity and polarization of a beam of light of wavelength  $\lambda$ . The first component,  $I_\lambda$ , is the actual intensity of the light; the  $Q_\lambda$  component represents the intensity of that portion of the light that is

linearly polarized parallel to some fixed direction  $\vec{i}$  in the plane perpendicular to the direction of propagation of the light; the  $U_\lambda$  component represents the intensity of that portion of the light that is linearly polarized at an angle of 45 deg with the fixed direction  $\vec{i}$ , and  $V_\lambda$  is the intensity of right-circularly polarized light.

Efficient operation of the RTSM requires a large, fast computer to handle in real time the volume of data comprising a magnetogram. The components of the magnetic field must be meaningfully displayed in real time. These requirements are met by computational support provided by the MSFC Computation Laboratory through the UNIVAC 1108 computer and D/TV system.

Video and audio lines link the observing site to the MSFC Communications Division, Building 4207; the Computation Laboratory, Building 4663; and the UNIVAC 1108 Remote Station, Building 4481. The magnetograph video intensity levels are converted through computer software programs to solar magnetic field values. This information is then relayed through Communications to the UNIVAC 1108 Remote Station and to the tower control room. Since the signal passes through Communications, the magnetograph images can be distributed to various video receivers throughout MSFC.

The RTSM will utilize the UNIVAC 1108 multiprocessor computer in all modes of operation. The extent of the use depends on: (1) the mode of operation, (2) the data mode being used, (3) the computational mode, and (4) the data display mode. The software for the RTSM is set up for operating in two modes, with the option of three modes for taking data and calculating and displaying the corresponding magnetic field values. In the first mode of operation (periodic mode), data can be taken in one of three data modes, operating continuously over a period of time,  $t_1$ , and then being dormant for a period of time  $t_2$ . In the second mode of operation (fast mode), data are put on magnetic tape for later analysis.

Input data from the RTSM tower are digitized and in the form of six matrices (128 by 128 raster) or in specific combinations of these six matrices, depending on the data mode of operation. The first four 32-bit words of the first line of each matrix of data are housekeeping data. Through computer programs for manipulating these matrices, calculations are made of the magnetic field values corresponding to the type of data taken. The RTSM software is capable of calculating the intensity of the longitudinal component, the intensity of the transverse component, and the azimuth of the transverse

component. This calculated magnetograph data can be displayed by D/TV, printer, and/or plotter. The characters have been designed and gray-scale levels developed so that the following data can be displayed on D/TV:

1. Intensity of the longitudinal component: gray scale.
2. Polarity of the longitudinal component: +white, -black.
3. Intensity of the transverse component: gray scale.
4. Azimuth of the transverse component: 45-deg increments.

Initially the printer and plotter will be used as backup equipment and later for a more detailed analysis.

# SKYLAB GROUND-BASED ASTRONOMY PROGRAM (SGAP)

By Bill J. Duncan

The Skylab Ground-Based Astronomy Program (SGAP) involves the acquisition, by a broadly based segment of the astronomical community, of corollary solar data from the ground simultaneously with the ATM observations from earth orbit. The need for such a program to gain maximum national benefit from the ATM expenditures was established by many recommendations of the scientific community.

In January 1971, the Office of Space Sciences at NASA Headquarters issued an announcement of opportunities for participating in the ground-based program and requested MSFC to manage certain subsequently selected tasks. Because of the scientific nature of the program, this effort was assigned to the SSL, which provides a project manager (this author) for overall coordination and planning activities; a project scientist (Dr. M. Hagyard) to work closely with the PI for scientific coordination, and task scientists to function as Contracting Officer's Representatives (COR) for the contracts resulting from the selected tasks. Insofar as possible, the selection of these task scientists was based on their own work in related fields.

The participating astronomical observatories and their associated projects are as follows:

1. The University of Hawaii is constructing a photoelectric differential coronal photometer for an observational investigation of coronal active regions. This instrument will measure simultaneously the intensities of several visible coronal lines suitably chosen for their diagnostic properties. Physical properties to be determined from these data are rates of energy loss and gain from the active regions, and the effects of flare events on the corona.

2. The Lockheed Missiles and Space Company (LMSC) will operate at the Kitt Peak's McMath solar telescope a system called spectroheliography that is capable of mapping the physical parameters of the solar atmosphere. In addition to the Kitt Peak solar telescope and vacuum spectrograph, a wide-exit aperture and a specially constructed movie camera capable of rapid film advance are used to obtain spectral maps of regions of the solar disk with high spatial resolution (to  $1/2$  arc sec). Velocity field as well as magnetic field maps are obtained.

3. The National Bureau of Standards (NBS) is upgrading its calibration capabilities in support of ATM-related measurements as a part of the SGAP program in the following areas:

a. A hydrogen arc source of known radiant flux for the calibration of spectrometric-detector systems over the region of 50 to 370 nm (500 to 3700 Å) is being developed.

b. A study is being conducted to determine the effects on photocathodes caused by the removal or addition of monolayers of contaminants in vacuum.

c. A capability is being established for radiometric calibration down to 20 nm (200 Å) by utilization of the NBS synchrotron facility.

4. The California Institute of Technology is installing the 65-cm functional verification unit (FVU) photoheliograph at its observatory at Big Bear Lake in California. The installation of the new vacuum photoheliograph will provide Big Bear with a large-aperture telescope capable of fully exploiting the site's excellent observing conditions. The new unit will be used, in conjunction with ATM, for extremely high-resolution studies of active regions.

5. The Lockheed Solar Observatory at Rye Canyon is preparing both its spar telescope systems for observations during the ATM mission. On one spar, studies in the D<sub>3</sub> line of HeI will direct attention to observing solar flares and transient events during periods of high disk activity and to prominence observations during periods of low disk activity. On the other spar, a telescope is being fitted with a filter for high-resolution photographic studies in CaII at 854.2 nm (8542 Å).

6. The University of California at San Diego is building a beam-switching photometer system for infrared observations of solar flares. The observing site is at Mt. Lemmon, Arizona, with observations to extend from the 700 μm region down to possibly 1 μm, utilizing the 152.4-cm (60-in.) Cassegrainian telescope.

7. The LMSC at Palo Alto, California, is conducting a theoretical study of helium emissions in the visible and ultraviolet from solar active regions. Calculations of the statistical equilibrium populations for a 19-level HeI and a 10-level HeII ion are being performed.

8. The Uttar Pradesh State Observatory in India is studying the dissociation and excitation equilibriums of various molecules in the photosphere, in spots, and in faculae. Detection equipment is being supplied to India on loan for an observational program using their existing horizontal solar telescope and its associated spectrograph.

9. The Applied Physics Laboratory of Johns Hopkins University is preparing to perform an observational program during the ATM of high time resolution spectral observations of solar radio bursts in the 500- to 100-MHz range.



# HYDROGEN-ALPHA SOLAR FLARE VIDEO TELESCOPE

By Edwin J. Reichmann

The Hydrogen-Alpha Solar Flare Video Telescope System (Fig. 9) is used at MSFC's SSL for photometric measurements of solar active regions. The active regions of the sun are scanned continuously to obtain changes in brightness and area as a function of time. Up to 10 regions on the solar disk are selected and scanned at intervals of approximately 10 sec. A quiet region and interesting active regions are scanned; the analog signal is digitized for storage on magnetic tape (Fig. 10). Small software programs are used to record (in real time) on strip chart records the peak brightness, the area of the active region above a selectable background level, and the region flux.

The solar data are in a format readily available as ground-based support data for the Skylab/ATM mission. In addition, the H-alpha data system is used in conjunction with the MSFC/SSL RTSM system. The H-alpha data correlated with solar magnetic field data from the RTSM system will provide valuable solar flare data, obtained under identical observing conditions, for ATM postmission in-depth studies of solar active regions.

Figure 11 is a plot of the digital data obtained with the video telescope system. The data from an active region which produced a small sub-bright flare are depicted. The horizontal scale indicates the active region brightness. Values 20 through 25 represent dark features; i. e., spots and filaments; values 25 through 40 represent the surrounding background features as seen in H-alpha light; and values 40 through 60 represent brightening above the background level which occurs during the flare. The vertical axis represents, on a logarithmic scale, the number of samples recorded at each brightness level. A set of such plots depicts the evolution of the active region over a period of time. This system has great promise as a method for obtaining reliable, consistent, photometric data for solar flare classification.

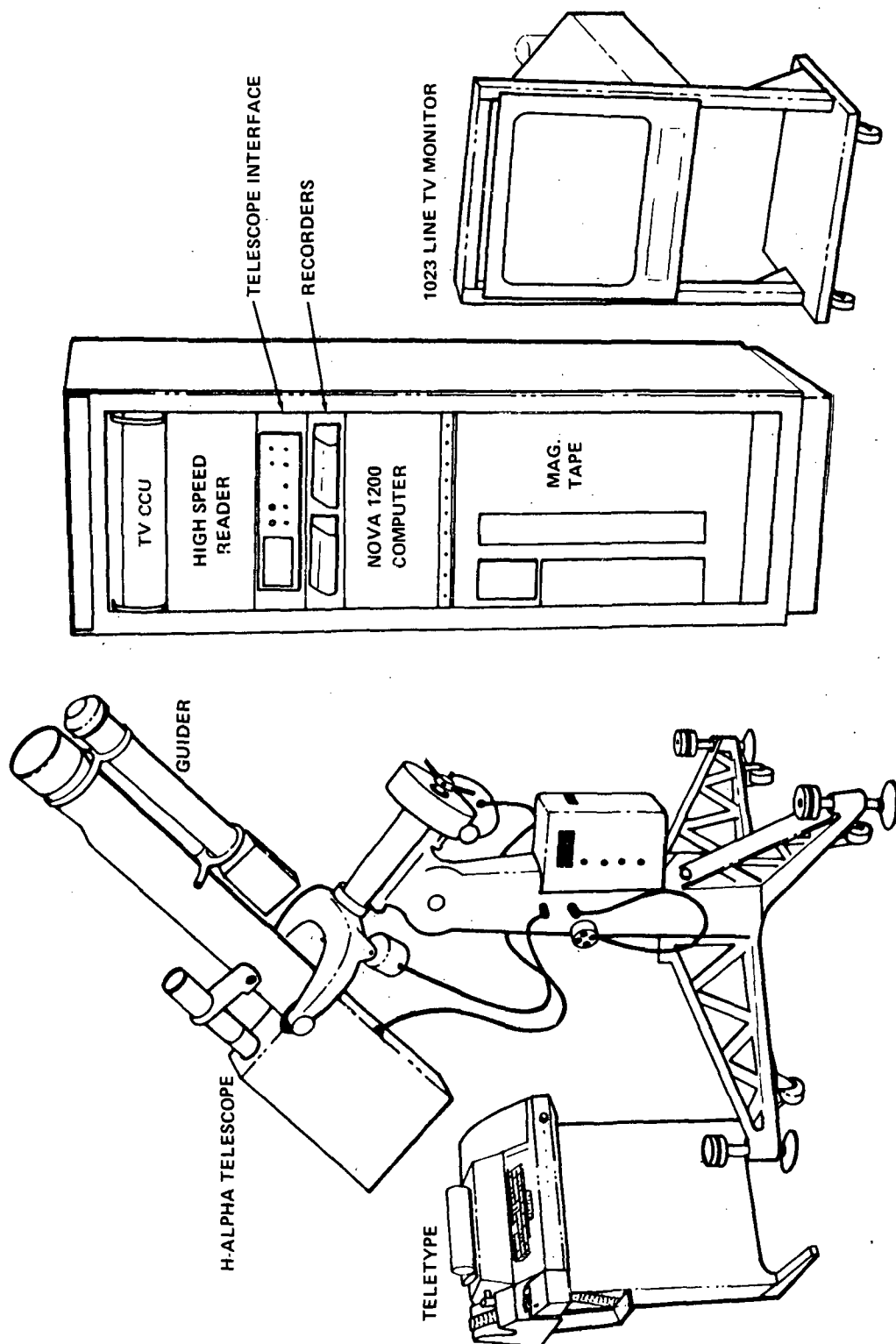
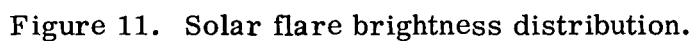
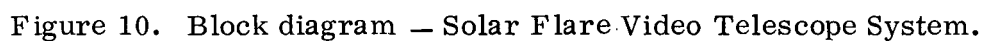


Figure 9. Hydrogen-Alpha Solar Flare Video Telescope System.



# GROUND-BASED MILLIMETER OBSERVATIONS

By Charles R. Baugher

## Basis for the Observation

In general, the very large antenna required for radio observations of the sun has restricted these measurements to ground-based observatories. However, since the earth's atmosphere is relatively transparent to radio signals, this restriction has not adversely affected the study of the sun in this region of the spectrum. At the longer and intermediate wavelengths, continuous comprehensive measurements have produced an extensive set of data which has provided a means of interpreting the physical processes of the sun's outer atmosphere. At the very short wavelengths, however, the radio observations have been very limited, primarily because of the complexity of the required electronic equipment and the lack of specialized observatories. Because these very short wavelength emissions originate from deep within the solar atmosphere and should be representative of the regions in which flare activity itself originates, the SSL initiated a millimeter wavelength observational program to coincide with the ATM program to provide this fundamental set of ancillary data.

## Review of Microwave Activity

Because solar observations at millimeter wavelengths have been relatively limited, it is generally desirable to consider the observations by comparing and contrasting the measurements with the better-understood centimeter wavelength emissions. In the centimeter wavelength region the majority of the measurements are obtained by a constant monitoring of the entire solar disk and by categorizing the activity according to its spectrum and temporal variations. During flare activity, intensive centimeter outbursts are observed which exhibit rise times and half-widths of a few minutes and correlate with the occurrence of the impulsive phase of the flare. In those cases where it has been possible to obtain position information on the event, it has been found that the location of these "impulsive bursts" correlates with the centers of activity. It is now fairly well established that these bursts are generated by a gyro-synchrotron mechanism during the ejection of relatively high energy electrons through the lower corona at the initiation of a flare and are closely connected with the hard X-ray bursts, although probably generated by different electrons.

The bursts often exhibit a high-frequency extension which is observable in the millimeter wavelength region, although it is generally of much lower amplitude and decreases further with decreasing wavelength. Since this lower amplitude necessitates the use of highly directional, high-gain antennas for significant observations in the millimeter portion of the spectrum, the observations have been limited by the availability of such facilities. However, on those occasions when observations across the millimeter band have been available, it has been possible to determine the energy distribution of the electrons responsible for the impulsive bursts.

In obtaining millimeter data on the impulsive type of bursts, a second somewhat slower and less intense burst, which appears to be thermal in nature, has been discovered. This second type of burst is generally observable only at the shorter wavelength end of the millimeter spectrum. The very limited data available have shown that these bursts correlate very well with the soft X-ray enhancements seen during flare activity, but such a relation is difficult to justify theoretically since the two sets of emissions are thought to originate in different levels of the solar atmosphere. Further data and analysis are required before any conclusions based on this phenomenon can be reached, and it would be of particular interest to compare millimeter and extreme ultraviolet (EUV) observations since present models indicate that these emissions do originate in the same regions.

## Description of the Millimeter Observations

To obtain data with which to make a more definite determination of solar activity in the millimeter wavelengths, observations at 8- and 3-mm wavelengths will be conducted during the ATM observations. The 8-mm wavelength observations will utilize an 18-m diameter parabolic antenna operated by the Naval Electronics Laboratory Center in San Diego, California, with the basic receiver electronics and technical coordination supplied by MSFC. This antenna exhibits approximately a 2-arc min resolution at this wavelength and is capable of conducting a computer-controlled mapping over the solar disk in 1 hr. The presently anticipated operating mode during the ATM flight will include a complete mapping of the 8-mm emissions once or twice a day, with the remainder of the observing time utilized to repeatedly map selected regions of activity.

The 3-mm wavelength data will be obtained from a 2-m diameter parabolic antenna operated at MSFC. This antenna exhibits approximately a 7-arc min resolution at the 3-mm wavelength and will be used to continuously track a selected active region during the daily observing period.

The coordinated efforts of the two receiving sites should provide heretofore unobtained solar data at two points in the millimeter spectrum and will be of particular significance when analyzed in conjunction with the variety of other measurements scheduled during the mission.

### III. MATERIALS SCIENCE/MANUFACTURING IN SPACE

By W. C. Snoddy

The SSL is involved in a series of Skylab experiments aimed at exploring the possibilities of exploiting the unique environment of space. Of particular interest are the potentially beneficial effects resulting from solidification in a near-zero gravity environment. This lack of gravity may, for example, decrease the microconvection processes which occur at the solid/liquid interface during crystal growth. This will perhaps reduce the number of defects in the resulting crystal and/or increase the homogeneity of any added dopants. Other techniques to be investigated include free-floating solidification which eliminates the possibility of container contamination and container-induced extraneous nucleation sites. The SSL involvement in Skylab is part of a continuing effort to develop an understanding of the fundamental physical processes underlying the Materials Science/Manufacturing in Space (MS/MS) program.

Table 5 lists the SSL participants in the MS/MS program.

TABLE 5. SSL MATERIALS SCIENCE/MANUFACTURING IN SPACE PARTICIPATION

Experiment or Function	Principal Investigator	SSL Role
M-512 Materials Processing Facility	Mr. P. Gordon Parks, MSFC	Mr. T. Bannister/ Mr. M. Davidson, Scientific Co-Investigators
M-551 Metals Melting	Mr. J. Williams, MSFC	Ms. B. Facemire, Scientific Co-Investigator
M-552 Exothermic Brazing	Mr. J. Williams, MSFC	Mr. D. Gates, Scientific Co-Investigator
M-553 Sphere Forming	Mr. E. Hasemeyer, MSFC	Dr. E. W. Urban, Scientific Co-Investigator
M-555 GaAs Crystal Growth	Mr. R. Siedensticker, Westinghouse	Mr. M. Davidson/ Mr. C. Schafer, Co-Investigators
M-556 Vapor Growth of IV-VI Compounds	Dr. H. Wiedemier, Rensselaer Polytechnic Institute	Mr. M. Davidson, MSFC Technical COR
M-558 Radioactive Tracer Diffusion	Dr. A. Ukanwa, MSFC SSL Research Associate (PI from SSL)	Mr. T. Bannister, Experiment Monitor
M-563 Growth of Mixed III-IV Compounds	Dr. W. Wilcox, University of Southern California	Mr. M. Davidson MSFC Technical COR



TABLE 5. (Concluded)

Experiment or Function	Principal Investigator	SSL Role
M-560 Spherical Crystal	Dr. H. Walter, University of Alabama in Huntsville	Mr. T. Bannister MSFC Technical COR
M-566 Copper-Aluminum Eutectic	Mr. E. Hasemeyer, MSFC	Dr. L. Lacy Scientific Co-Investigator
Mathematical Simulations for Space Processing Experiments		Mr. J. Parker, Experiment Scientist

## EXPERIMENT M-512 – MATERIALS PROCESSING FACILITY

By Tommy C. Bannister and Mirt C. Davidson

The Materials Processing Facility or workbench shown in Figure 12 provides a common spacecraft interface for a group of 15 experiments in materials science and technology and demonstrates a "facility approach" in which common hardware will be used to perform multiple experiments. Certain basic manipulations, such as heating and cooling and the maintenance of vacuum and controlled atmosphere, will be common to several experiments. The most significant differences between experiments will be in the materials used and the values of the process variables, such as time, temperature, pressure, and atmospheric composition. This facility provides a most effective means of implementing these experiments, with commonality emphasized. Each of the experiments is scientifically supported by various disciplines in the SSL in a variety of ways; e.g., PI, Scientific Co-Investigator, Scientific Consultant, COR, and also by ground-based research programs.

The facility itself consists of a rack with a 40.6-cm (16-in.) work chamber with an adjacent electron beam, utility outlets, storage areas, and a control panel. Each experiment is mounted in the chamber during experimentation. The chamber has an access port, a photography port, and a vacuum port. Two experiments use the electron beam as a heating source, one uses exothermic heating in a self-contained package, one uses resistance heating in its own package, and the remaining 11 experiments are run in the Multipurpose Furnace (M-518) which mounts into a cavity inside the chamber. Figure 12 shows this furnace in place in the M-512 facility. The scientific work is best discussed by considering the individual experiments.

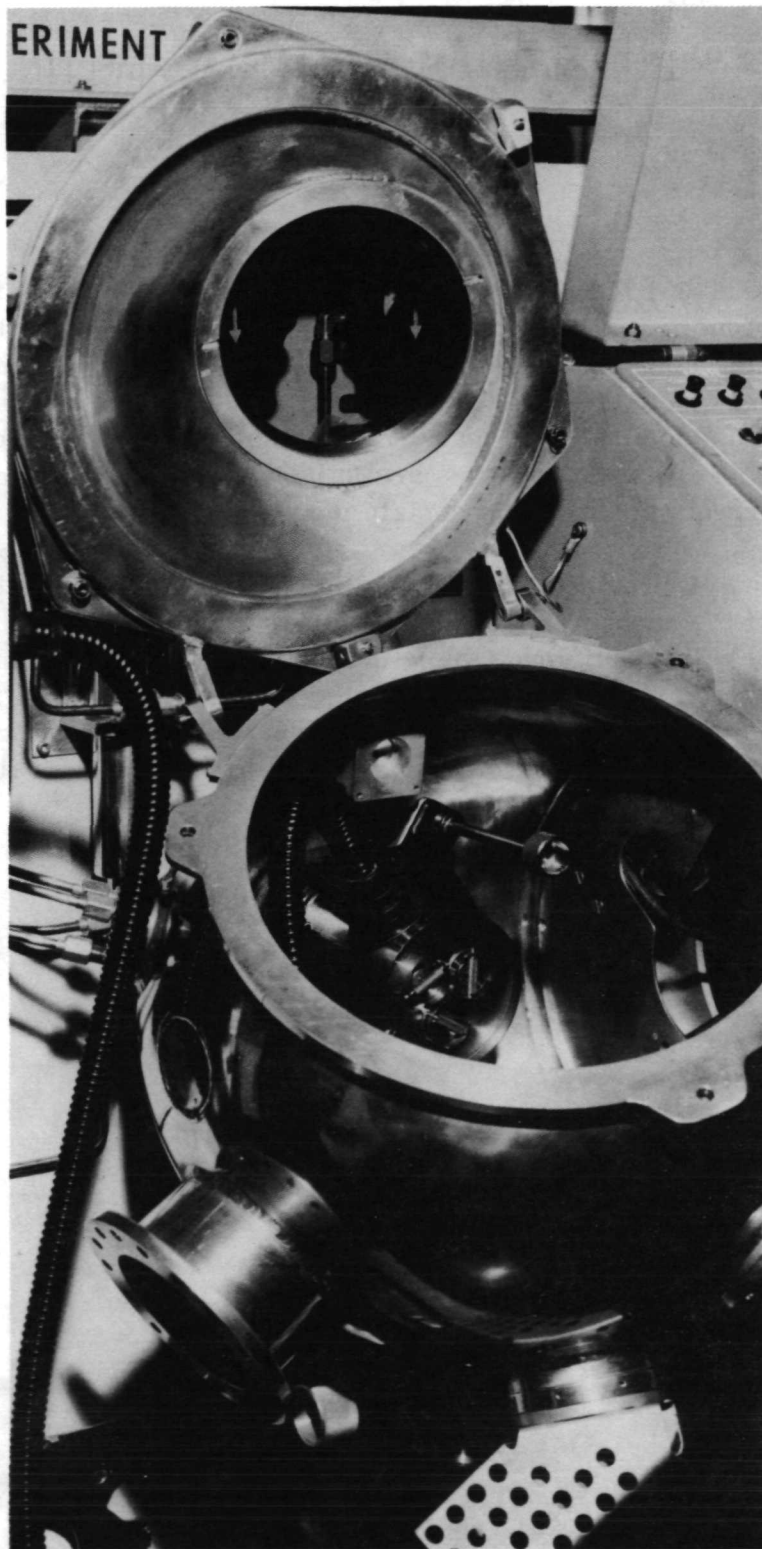


Figure 12. M-518 Multipurpose Furnace mounted in the M-512 Materials Processing Facility.

## EXPERIMENT M-551 – METALS MELTING

By Barbara Facemire

The M-551 Metals Melting Experiment is designed to study the behavior of molten metals and to test means of joining metals by electron-beam welding in a space environment (Fig. 13). Solidification processes in metals are expected to behave differently in space. Heat transport by conduction should dominate and mass transfer should be dominated by diffusion. On earth both of these processes are influenced heavily by circulating convection currents in melts that contain temperature gradients.

The SSL provides a Scientific Co-Investigator (this author) for this experiment to enhance the scientific return. Her responsibility is to participate actively in identifying sample materials; developing sample preparation, characterization, and evaluation techniques; and performing ground-based studies and investigations. The Scientific Co-Investigator works closely with the PI and scientists from industry who have the task of finalizing the experimental procedures.

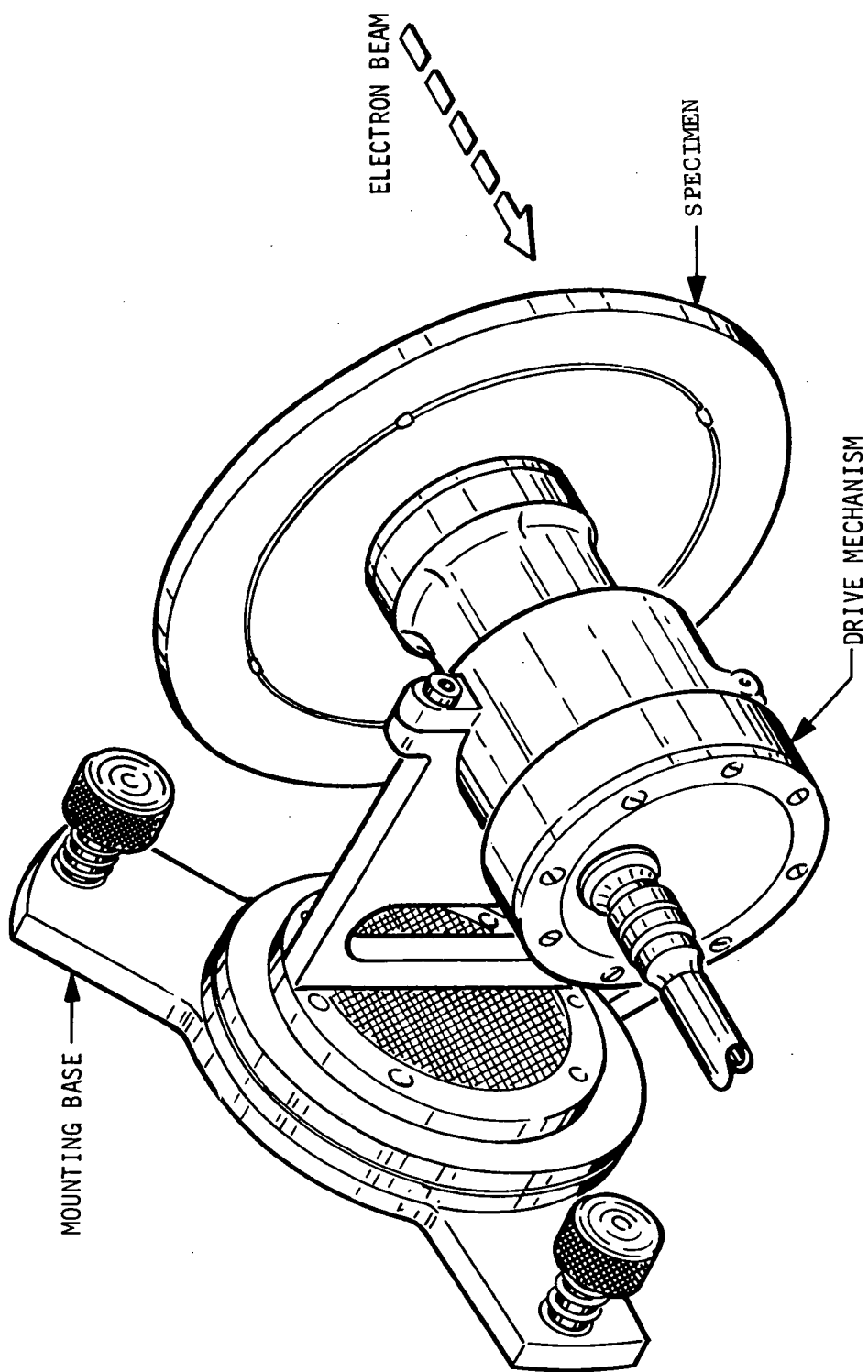


Figure 13. M-551, electron beam welding.

## EXPERIMENT M-552 – EXOTHERMIC BRAZING

By Daniel W. Gates

The Exothermic Brazing Experiment is designed to develop a technique for brazing components in space repair and maintenance operations. This includes a study of surface wetting and capillary flow effects in molten metals and the flow and solidification of the braze metal. It is planned to join four 1.91-cm (0.75-in.) 304-L stainless steel and nickel tubes with a silver-copper-lithium braze alloy. Figure 14 shows the experiment package in some detail. An exotherm material is used as the heat source. The package of four tubes is placed in the M-512 chamber (Fig. 15). Temperatures above 790°C are developed to melt the braze alloy, and the 304-L SS or Ni tubes are wetted, cooled, and brazed. The entire package is returned to be examined and evaluated. The only variable parameter planned is the gap to be filled with brazing alloy.

The Scientific Co-Investigator has made several suggestions about the experiment. Pure nickel, in addition to 304-L SS, is to be used for an easier analysis of results. Microprobing across the wetted section could be more easily accomplished if the braze composition did not contain the elements of the material to be brazed. Exotherm outgas products and their effect on the braze should be determined. The tube and sleeve to be brazed to it should not be concentric in all four cases but should form a tapered gap in two of the tubes, and the amount of braze material should be limited so as not to completely fill the gap. This will allow for determining the shape of the meniscus formed by the braze material and the two joined surfaces. Finally, a temperature-versus-time curve should be made to follow the reaction process. A concentric Ni tube is to be modified to include a radioactive tracer in the braze alloy so that both flow and penetration from one-eighth of a circular original rim section can be observed. All suggestions have been accepted and are being incorporated in the flight experiment.

Scanning electron microscope (SEM) photographs of braze cross sections and X-ray analysis across the braze, to be done in the SSL as well as by contract, have been proposed for after the flight.

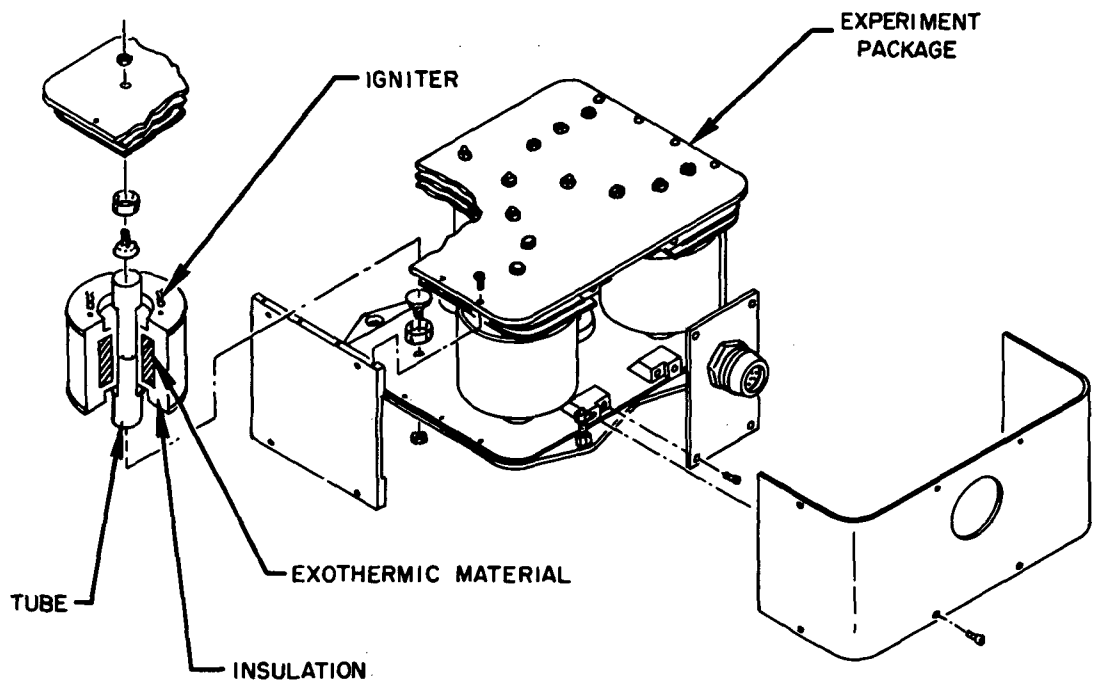


Figure 14. Exothermic Brazing Experiment Package, M-552.

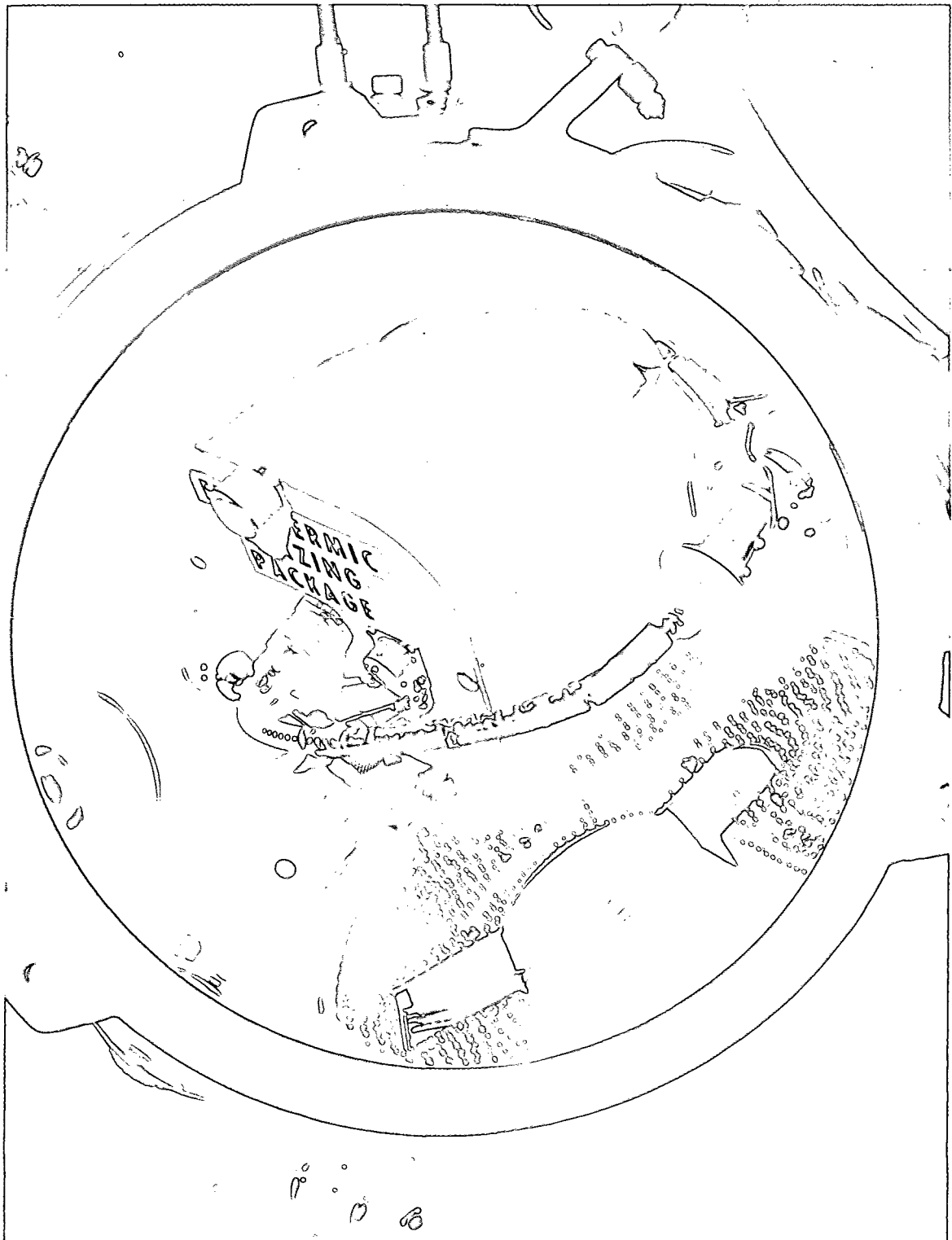


Figure 15. Exothermic Brazing Package in M-512 chamber.



## EXPERIMENT M-553 — SPHERE FORMING

By Eugene W. Urban

The purpose of the free form solidification experiment, formally termed the Sphere Forming Experiment, is to demonstrate the unique effects of zero gravity on the fundamental solidification phenomena of pure metals and alloys. Figure 16 shows the experiment in the M-512 vacuum facility. Twenty-eight cylindrical metal specimens mounted on two pinwheels are sequentially rotated into an electron beam, melted, and allowed either to float free and resolidify without physical contact (22 samples) or to remain on a support shaft during resolidification (6 samples). The zero-gravity environment is expected to affect solidification primarily by eliminating thermal convection currents which exist in a gravitational environment because of density variations. The absence of physical contact should permit some of the specimens to undercool (cool below their melting temperature without solidifying) considerably. Thus their eventual solidification should occur in a manner which is quite different from that commonly observed, and the resulting metallurgical structure should have interesting differences.

The SSL has made a number of contributions to M-553, including analysis which has permitted hardware and procedural improvements and consultation to attempt to increase the amount of scientific information to be gained from the experiment.

High-frame-rate films have been analyzed to estimate the trajectory and time of free-fall of the samples which were melted during the first KC-135 aircraft zero-gravity experiment. These results have led to modification of the specimen holders to permit more controlled sample release and greater zero-gravity cooling time. Calculations were made of the approximate air flow forces on the solidified samples during the suction collection process after the experiment is complete. This analysis has contributed to changes in astronaut procedures. Measurements have been made to determine the thickness and light absorption of the metallic layers deposited on viewport windows by evaporation from the surfaces of the melted specimens.

The M-553 hardware and operating procedures have been carefully studied for possible simple modifications which would enhance the scientific returns from the flight experiments. Suggestions were made to extend the

camera running time to provide a photographic record of the free-floating molten samples. This would permit some degree of trajectory analysis, would show possible droplet oscillations and give some information about viscosity, could allow observations of the solidification process, and should permit some estimate about the sample temperature history. Through proper preflight or postflight calibration of the film color response to metal specimens of known temperature, it could be possible to obtain some data on the temperature history of the specimen. From this the rate of radiative cooling could be estimated, even if final solidification occurred outside the camera field of view. This, together with the trajectory information, could permit a sample temperature at the time of wall contact to be inferred.

It was also suggested that some type of unique sample identification be provided. For example, inclusion of a minute trace of  $\text{Ni}^{56}$  (which emits a 0.17-MeV gamma ray) in one Ni specimen would permit it to be distinguished from another Ni specimen containing a trace of  $\text{Ni}^{57}$  (which emits a 1.368-MeV gamma ray) and from a pure nickel sample. Because specimen collection appeared to be difficult to accomplish rapidly, we suggested that a small magnet could be employed to collect the specimens, all of which are ferromagnetic, once they have cooled below their Curie temperatures.

Although potentially quite useful, none of the above suggestions could be adopted, primarily because of unacceptable hardware modifications and concern with deleterious effects of the additional radioactivity and magnetic fields.

Finally, the SSL is planning to participate in the physical characterization of the flight and ground control specimens. Several nondestructive measurements have been proposed, including room temperature resistivity and magnetic susceptibility, resistivity ratio (ratio of room temperature resistivity to that at liquid helium temperature, 4.2°K), Curie temperature, and temperature variation of susceptibility. These techniques would provide useful information about impurity distributions, crystal defects, atomic order, and alloy composition and would complement the physical and metallurgical measurements to be performed by the other members of the M-512 science support team. It appears now that the measurements which will require raising specimen temperature somewhat (Curie temperature) and lowering it drastically (resistivity ratio and temperature variation of susceptibility) will not be done until after the science team has completed a detailed metallurgical analysis.

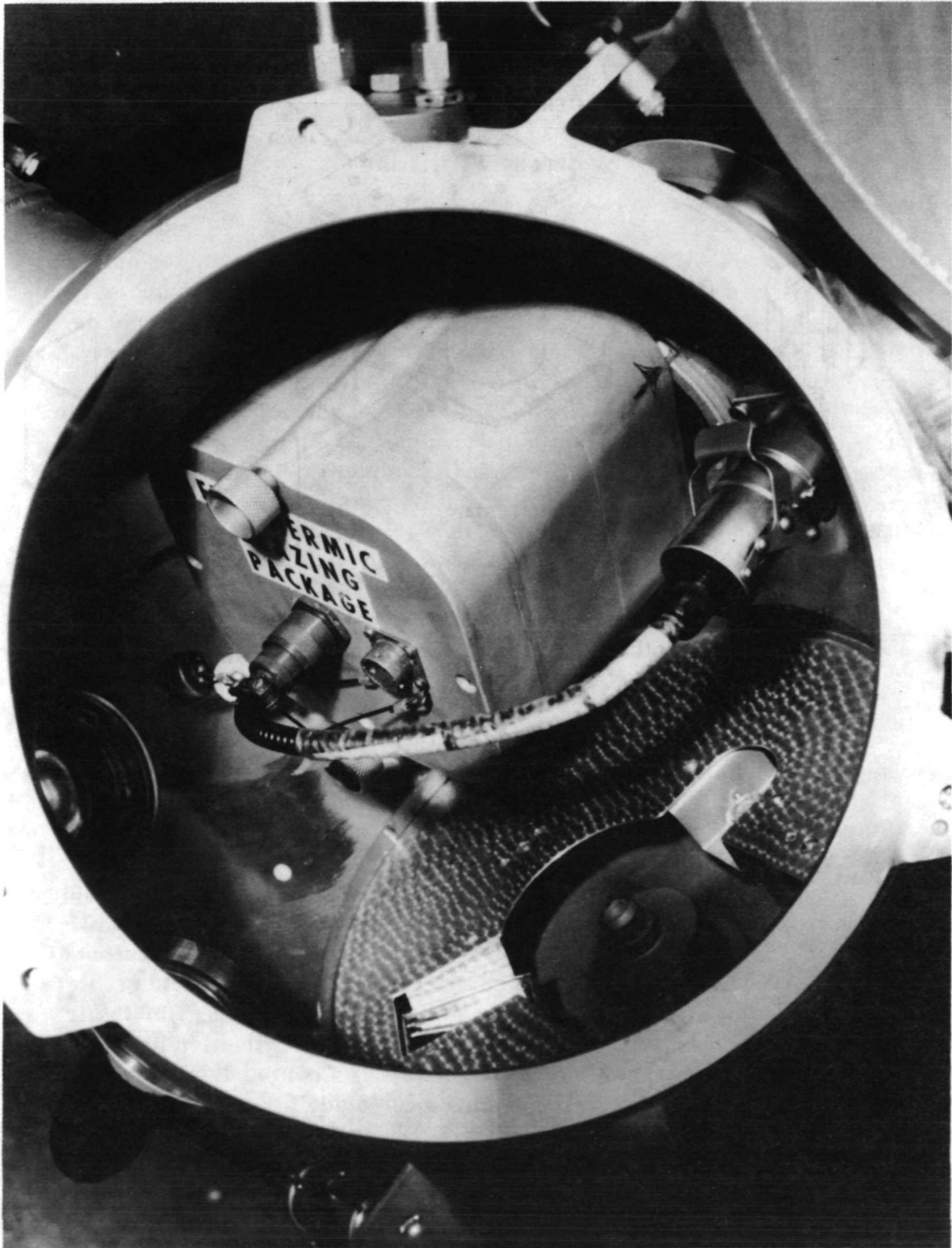


Figure 15. Exothermic Brazing Package in M-512 chamber.

## EXPERIMENT M-555 — GaAs CRYSTAL GROWTH

By Mirt C. Davidson

The objective of this experiment is to grow gallium arsenide crystals from solution to produce a material of high chemical and crystalline perfection. Figure 17 shows a crystal growth ampoule. The elimination of convection flow generated by thermally induced density variations is a significant aspect of crystal growth in space. The resulting crystals should demonstrate the chemical homogeneity and structural perfection attainable when earth-type fluctuations are eliminated. Three ampoules containing a gallium arsenide seed and source immersed in liquid gallium are packaged in an insulated container. The gallium arsenide is transported by diffusion down the ampoule to a seed at the cooled end where the single crystal is grown epitaxially on the gallium arsenide seed. The experiment was proposed by Westinghouse. The SSL is providing the MSFC with Co-Investigators for this experiment and, as such, is pursuing a major and extensive ground-based program of epitaxial crystal growth and subsequent characterization. Three operational problems became apparent early in the program: mechanical stress on the crystal caused by the gallium solvent freezing, spurious growth during cooldown, and dissolution of the seed crystal before growth. The SSL studies have indicated that the freezing stress introduces dislocation densities in the range of  $10^4$  to  $10^5/\text{cm}^2$ . This is a high dislocation density; therefore, if at all possible, the gallium should not be allowed to freeze. Present indications are that the spurious growth during cooldown is not significant. Seed dissolution, however, remains a problem which has no satisfactory solution at present.

The characterization techniques employed include metallographic analysis and X-ray analysis, including X-ray topography, etch-pit count, resistivity, and Hall-effect measurements. A no-contact alternating current resistance and Hall-effect technique is being developed under contract at the University of Alabama in Huntsville.

Doping of one or two of the ampoules is being considered. This would enhance the experiment and could help to distinguish the epitaxial layers from the substrate. A silicon-doped layer on a pure seed and a pure layer on a silicon-doped seed will be used. The growth of these epitaxial layers is a currently active area of applied research in the SSL.

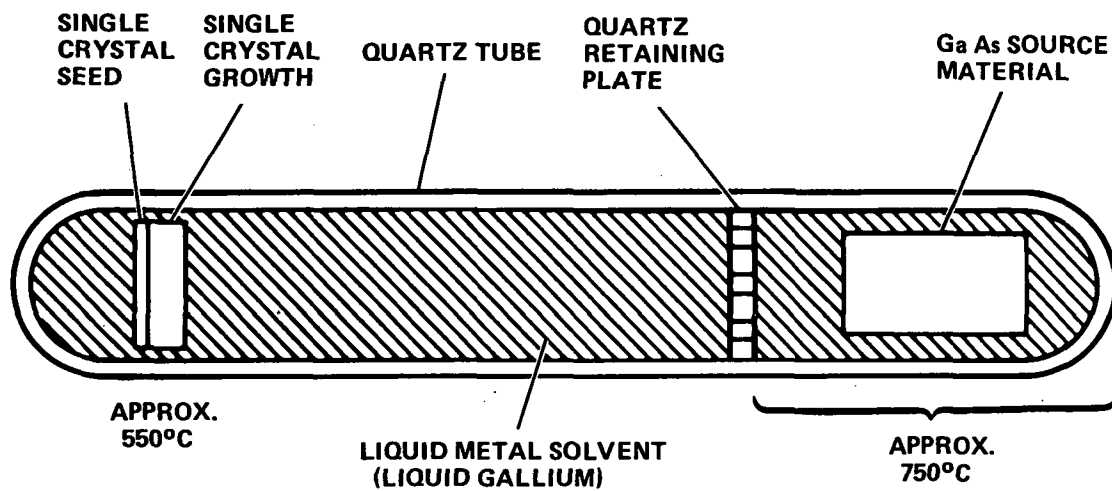


Figure 17. GaAs single crystal growth ampoule, M-555.

## EXPERIMENT M-556 — VAPOR GROWTH OF IV-VI COMPOUNDS

By Mirt C. Davidson

Experiment M-556 — Vapor Growth of IV-VI Compounds consists of the vapor growth of GeTe and GeSe with  $\text{GeI}_4$  as the transport agent. The experimental arrangement consists of a quartz ampoule containing the source material (GeTe or GeSe) and the transport agent at one end. This ampoule is placed in a thermal gradient, and the material is deposited at the cool end in the form of single crystals. This experiment was proposed by Dr. H. Wiedemier of Rensselaer Polytechnic Institute (RPI).

Marked differences in the crystalline perfection (structural) and morphology have been observed by changing the vapor pressure of the transport agent. After studying the transport rate, it was concluded that the degree of convective transport was the determining factor. Experiment M-556 is designed to verify this conclusion and allow the separation of convective effects from growth rate effects.

The SSL is responsible for the technical coordination of this experiment. The in-house effort is concerned primarily with the electrical characterization, which includes photovoltaic scan, resistivity, and Hall-effect measurements. In addition, X-ray topography will be used.

## EXPERIMENT M-558 — RADIOACTIVE TRACER DIFFUSION

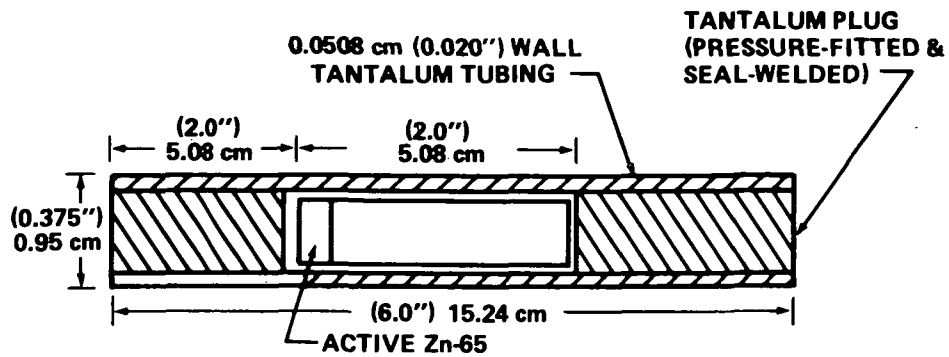
By Anthony O. Ukanwa and Tommy C. Bannister

Experiment M-558 — Radioactive Tracer Diffusion is an SSL experiment designed to be performed in the cartridge chamber of the Multipurpose Electric Furnace of the M-512 facility in Skylab A at temperatures not to exceed 800°C. The objective of the experiment is to acquire data on the distribution and diffusion of a small layer of radioactive zinc through neutral zinc under near-zero-gravity conditions and thermal conditions of melting. Figure 18 shows a cross section of the experiment ampoule.

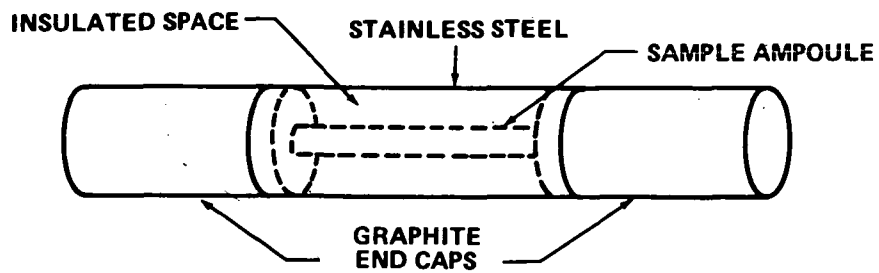
A zinc rod carrying a small section of radioactive zinc (Zn-65) in one end is encapsulated in tantalum to form an ampoule. Tests in which the ampoules were heated to 1000°C for 2 hr have shown that the molten zinc is compatible with tantalum but attacks stainless steel. These tests were made for the SSL at the Oak Ridge National Research Laboratory as a first step in the fabrication of the ampoules. Each ampoule is enclosed in a stainless steel tube with graphite end caps to form a cartridge. The level of radioactivity is less than 13  $\mu$ C per cartridge. The work of the astronaut performing the experiment is limited to loading a set of three cartridges into the furnace, setting a temperature program, and unloading the cartridges from the furnace for stowage at the end of the experiment run. The heat-soak period under a temperature gradient is 16 hr.

The long half-life of Zn-65 (245 days) will permit the preservation of the distribution of the radioactive zinc until a postflight ground-based analysis of data can be completed. These data will show the distribution of Zn-65 caused by diffusion and any convection present. A comparison of the flight data, ground-based preflight data, and theoretical diffusion coefficients calculated from Fick's law of diffusion will reveal the effect of zero-gravity convection on the test sample. The penetration of Zn-65 into neutral zinc in 16 hr by diffusion alone is not expected to be deep; however, bulk convection can cause a considerable penetration in such a period.

The PI for this experiment is a postdoctoral resident research associate presently assigned to the SSL by the National Research Council. The SSL also furnishes a scientific experiment monitor for this effort. The radioactive ampoules are being fabricated for the PI at the Oak Ridge National Research Laboratory. The ampoules will be integrated into the cartridges at the Westinghouse Research Development Center, which is the fabricator of the Multipurpose Electric Furnace.



a. Section of a sample ampoule.



b. Cartridge.

Figure 18. Radioactive tracer diffusion ampoule and cartridge, M-558.



# EXPERIMENT M-560 – SPHERICAL CRYSTAL

By Tommy C. Bannister

Experiment M-560 is designed to study solidification of a seeded, containerless melt of indium antimonide. The Multipurpose Electric Furnace will be utilized to process three cartridges. The PI, Dr. H. U. Walter, is with the University of Alabama in Huntsville. The MSFC technical monitor for this experiment is a member of the SSL.

The University of Alabama in Huntsville is responsible for the development of this experiment and for the evaluation and analysis of the results obtained. The major objective of the experiment is to study the feasibility of a containerless growth technique and to obtain information on chemical homogeneity and structural perfection of space-processed semiconductor crystals.

## EXPERIMENT M-563 — GROWTH OF MIXED III-IV COMPOUNDS

By Mirt C. Davidson

Experiment M-563 — Growth of Mixed III-IV Compounds consists of the Bridgeman growth of  $\text{Ga}_x\text{In}_{1-x}\text{Sb}$ , with  $x = 0.9, 0.7$ , and  $0.3$ . The experimental arrangement consists of the appropriate stoichiometric ratios enclosed in a quartz ampoule. The material is melted and unidirectionally solidified to produce homogeneous single-crystalline material. If produced with appropriate chemical and structural perfection, these semiconductors offer a continuous spectrum of band-gap energies and optical properties from which to choose. This experiment was proposed by Dr. W. Wilcox of the University of Southern California (USC).

The presence of convective-induced thermal oscillations in the melt produces instantaneous growth rates much larger than the mean growth rate. At these high mixed ratios ( $x = 0.9, 0.7$ , and  $0.3$ ), constitutional supercooling results and produces interface breakdown. In the absence of gravity, these oscillations should not be present.

The SSL is responsible for the technical coordination of this experiment. The in-house effort is concerned primarily with characterization, including electrical and X-ray characteristics.

# EXPERIMENT M-566 — COPPER-ALUMINUM EUTECTIC

By Lewis L. Lacy

The unique microscopic structure of directionally solidified eutectic alloys shows promise of several potential applications ranging from high-temperature structural applications to electronic materials with unique superconducting, semiconducting, or insulating properties. Experiment M-566 — Copper Aluminum Eutectic is an attempt to obtain improved lamellar structure by solidifying a eutectic composite in the absence of thermal convection. In the 1-g environment, unidirectionally solidified eutectics always exhibit termination faults. Although the origin of these faults is unknown, it has been postulated that thermal convection is significant in their formation. When a eutectic composite is fabricated in the absence of thermal convection, new insights may be obtained into the parameters affecting the lamellar structure, and more perfect structures may result. The Al-Al<sub>2</sub> Cu eutectic is contained in three cylindrical crucibles, which are placed in the Multi-purpose Electric Furnace. The alloy is melted and then solidified under controlled conditions. This alloy was chosen because of its low eutectic temperature and the available background information.

The SSL provides the Scientific Co-Investigator for this experiment. He has been instrumental in establishing the physical characterization of the ground control and flight samples. The potential usefulness of a zero-gravity environment in forming composite castings cannot be ascertained until the necessary ground-based experimental studies are performed. The general objectives of the ground-based studies are to provide a quantitative measure of the effect of a zero-gravity environment on the unidirectionally solidified eutectic Al-Al<sub>2</sub> Cu. Several in-house studies are designed to meet these objectives:

1. Ultrasonic characterization consists of investigating the propagation of high-frequency sound (1 MHz to 200 MHz) in the samples to determine nondestructively some of the mechanical and physical properties of the material, such as elasticity (Lame's and Young's moduli) and the existence of voids and grains. Since the samples will probably be anisotropic in their ability to propagate sound, ultrasonic velocity and absorption measurements also should give a quantitative indication of the relative improvement in the lamellar structure of the flight sample.

2. Three different methods of determining resistivity have been established to aid in the characterization of the sample. Since the resistivity of the two materials in the composite casting is different, resistivity measurements will provide a direct indication of the possible improvement of the lamellar structure. The ratio of resistivity at room temperature to the resistivity at liquid helium temperature will be measured because it provides a direct method for quickly determining the relative purity of the samples. If possible, separate resistivity ratios of the two component materials of the composite casting will also be determined. The local resistivity along the length of the material will also be measured to determine the homogeneity of the sample.

3. Scanning electron microscopy will be used to directly view the microscopic structure of the sample to determine whether convection currents in the ground control sample help to break up or terminate the lamellar structure. The interface between the lamina will be examined at high magnification to determine the possible existence of oxides and to gain some insight on the relative amount of diffusion of one component material into the other. The relative sharpness of the boundary between the two phases should be an excellent indication of the effect of local convection on the solidification process.

# MATHEMATICAL SIMULATIONS FOR SPACE PROCESSING EXPERIMENTS

By James W. Parker

In the M-553 Sphere Forming Experiment it is assumed that the floating time will be long enough for the molten spheres to solidify before striking the chamber wall. To determine the expected float dynamics versus the various orbital and operational parameters, the entire experiment has been formulated mathematically. This simulation furnishes the following data:

1. The optimum time for conducting the M-553 experiment.
2. The maximum float time to be expected.
3. The acceleration levels to be expected.
4. The path followed by the molten spheres after release.
5. The direction of the g-vector at all times for the M-553 experiment.

At present these calculations include the forces on the spheres caused by the gravity gradient, inertial, and Z-local vertical control system. These studies are also useful to the other MS/MS PI's for determining the forces on their material during processing.

## IV. OPTICAL CONTAMINATION

By Robert J. Naumann

### Introduction

As space experiments develop in complexity and sophistication, the problems of interference from the self-induced local environment become more severe. Extreme care in design and operational procedure is demanded to insure that the experiments measure the intended phenomena rather than extraneous self-induced environmental effects. Optical experiments, particularly those operating in the far ultraviolet (UV), are highly susceptible to contamination from self-induced atmosphere; hence, the study of such interference is referred to as optical contamination or, in a more general sense, contamination.

A number of experiments on both manned and unmanned spacecraft have failed or have been severely degraded because the effects of contamination were not considered. Scattered light from ice crystals or other debris has prevented astronomical observations in the sunlit portion of the orbit. Windows and other optical surfaces have become coated with contaminating films and globules which produce scattering and adsorption. Since organic molecules are particularly good adsorbers in the far UV, a film of only a few monolayers can destroy the usefulness of a mirror or grating. Cooled infrared detectors have become coated with layers of ice from condensing water vapor. Mass spectrometers have become swamped by water vapor and other outgassing products. High-voltage power supplies have been destroyed by arc-over because the ambient pressure was not yet below the corona region when the high voltage was activated. Such difficulties are not restricted to the operation of experiments in space; many optical surfaces have become contaminated in vacuum chambers during tests.

The SSL was assigned to conduct research on the problems of optical contamination, to apply the results of this research to the problems concerning Skylab through our representatives on the Contamination Control Working Group (CCWG), and to work with the MSFC Systems/Products Office to implement design and procedural changes for the Skylab to reduce the threat of contamination to the various experiments. Table 6 lists the key SSL personnel in the Optical Contamination Program.

TABLE 6. KEY SSL PERSONNEL IN THE OPTICAL  
CONTAMINATION PROGRAM

Personnel	Function
Mr. Hoyt M. Weathers	Program Manager Chairman, SSL Contamination Committee Member, Skylab Contamination Control Working Group (CCWG)
Dr. James B. Dozier	ATM Project Scientist Member, SSL Contamination Committee Member, Skylab CCWG
Dr. Robert J. Naumann	Program Scientist Member, SSL Contamination Committee Member, Skylab CCWG Experiment Scientist, T-027 Sample Array Principal Scientist, Skylab Induced Atmosphere
Mr. Paul Craven	Member, Skylab CCWG Experiment Scientist, T-027 Photometer Principal Scientist, Skylab Windows
Mr. W. W. Moore, Jr.	Member, Skylab CCWG Principal Scientist, Quartz Crystal Microbalances (QCM's) on T-027 Sample Array Responsible Scientist, Skylab QCM's, QCM's on Integrated Real-Time Contamination Monitor (IRTCM), Particle Spectrometer on IRTCM
Mr. James M. Zwiener	SSL Scientist, Ground Contamination Principal Scientist, Active Cleaning Technique (ACT) Principal Scientist, Passive Contamination Monitoring Device (PCMD)
Dr. Thomas R. Edwards	Principal Scientist, Mass Spectrometer on IRTCM
Mr. Roger C. Linton	Principal Scientist, Optical Effects Module on IRTCM
Dr. Palmer N. Peters	Guest Experimenter, T-027 Sample Array

This type of problem was recognized as being extremely critical to the ATM experiments and other Skylab experiments. Since the ATM must operate in the sunlit portion of the orbit, the problem of scattering from particulate debris cannot be avoided. Therefore, extreme care must be taken to prevent the production of particulates. Also, because many of the measurements are made in the XUV, where obtaining good reflectivity is a difficult problem, the deposition of even a monolayer of an organic contaminant cannot be tolerated. For this reason extreme care must be used in selecting the nonmetallic material to be used in the vicinity of optics. Also, elaborate precautions must be taken in the storage and during vacuum testing of the optics to prevent the deposit of dust particles, outgassing products, and vacuum pump oil. All structures must be as dust free as possible to prevent such particles from forming a debris cloud in orbit or depositing on the optics during boost. Care must be taken to vent all possible sources of outgassing material and regions that contain trapped atmospheric gasses so that pressures in the vicinity of high-voltage systems will rapidly fall well below the corona regime, and measurements for verifying that the pressure is, in fact, low enough are required before the activation of high-voltage systems.

There was particular concern over the life-support system, which requires that large quantities of expendables and waste products be disposed of in a manner that will not interfere with the experiments.

## Assessment of the Problem

The Ball Brothers Research Corporation, under the direction of the SSL, performed a detailed assessment of the contamination problem on the ATM in 1967. This study identified the nonmetallic sources on the Skylab and determined the outgassing rates. It was shown that a freely expanding cloud of molecular material posed no problem through adsorption or scatter but that scattering from particulate material was a severe threat. The possible condensation of materials on optical surfaces was also identified as a possible threat.

In conclusion this study recommended, among other things, that a program of ATM material configuration management be conducted to eliminate particularly troublesome outgassers. This is especially important for the materials actually used inside the ATM canister because during boost and insertion into orbit the ATM aperture doors will be closed. The canister will then be vented through small ports. During this time the outgassing rate is



at its maximum, and, being somewhat confined, the outgassing molecules have many opportunities to condense on optical surfaces. Therefore, the choice of materials is critical. Parameters of concern are the rate of outgassing or fractional weight loss, the molecular weights of the outgassing products, the quantity of condensable outgassants, and the sticking coefficients and stay-times of the contaminating molecules on the various surfaces in the ATM canister.

The SSL performed preliminary weight-loss measurements and a mass spectrometric analysis of the outgassing products for a number of ATM materials. It also worked with the CCWG to establish meaningful criteria for material selection based on weight loss and mass number that could be rapidly applied to the vast number of nonmetallic materials considered for use. The actual screening of materials was done by the MSFC Astronautics Laboratory.

A major supporting research and technology (SRT) program was developed by the SSL under the sponsorship of the NASA Office of Aeronautics and Space Technology to investigate the remaining aspects of the problem. A comprehensive library of mass spectral fingerprints has been compiled for most of the nonmetallic material used in space applications. This library, together with automated computer-controlled data acquisition and analysis techniques developed by the SSL, allows rapid identification of contaminants.

Quartz crystal microbalance (QCM) techniques have been developed for measuring the amount of condensable material outgassing from a particular source, determining sticking coefficients, and measuring stay-times from which the contaminant surface heat of vaporization can be inferred. Some of the techniques can advance the state of the art in surface physics because of the ability to directly measure the mass deposited to accuracies of  $10^{-10}$  gm/cm<sup>2</sup>.

Optical techniques such as dark-field holography, modulation transfer function analysis, ellipsometry, microscopic holography, and interferometric holography have been developed to optically characterize surfaces. The latter technique shows particular promise for making vacuum in-situ morphological measurements of thin film growth. Additional surface characterization capabilities exist in the SSL, including scanning electron microscopy, electron microprobe analysis, Auger electron analysis, and low-energy electron diffraction (LEED), and are being used to study the migration of contaminating molecules on surfaces. A program is being planned with the University of

Alabama in Tuscaloosa to measure the effect of thin contaminating films on the work functions of surfaces using field-emission microscopy. These more basic studies are directed toward understanding the actual mechanisms that bond the contaminating molecule to a surface, which determines whether the molecule sticks more or less permanently or reevaporates rapidly. Of particular significance is how these bonding mechanisms are affected by the space radiation environment. The adsorption of a photon in some cases may supply the heat of evaporation required for the molecule to leave the surface (flash desorption) or, depending on the energy requirements, may provide the activation energy to convert the contaminating molecules into higher molecular weight compounds or to chemisorb on the substrate, resulting in a more or less permanent bond. For optics such as the ATM, where the optical surfaces are exposed directly to the sun, this process may be extremely important. There is also the possibility of free radical production by photolysis of out-gassing products or by collision with ambient atmospheric molecules. Such free radicals are highly active chemically and may be a contamination threat. These are also being studied at present.

The SSL has developed an excellent VUV, XUV, and X-ray capability to study the effects of contaminants on optical surfaces. It was shown that the reflective property of grazing incidence X-ray mirrors was strongly influenced by the presence of contaminants. The extreme susceptibility of far-UV optics to thin layers of contaminants was demonstrated, and it was found that the optical performance of a contaminated optic could be predicted by analyzing the reflectance from a multilayered surface if the optical constants of the contaminant and substrate were known.

Various cleaning techniques have been investigated, ranging from the evaluation of the cleaning kit to be used by the Skylab astronauts on optics accessible to them, to the development of active cleaning techniques consisting of in-situ ion bombardment of optical surfaces to rejuvenate contaminated optics. The ability of the latter technique to restore UV optics to their original performance has been demonstrated, and this technique has actually been used to improve the transmissivity of the aluminum XUV filters to be used on the NRL's ATM experiment.

The expertise of SSL scientists has been sought to solve many problems arising during ATM development. One of the SSL resident research associates, Dr. Cowan, a recognized authority on diffraction gratings, contributed to the identification and solution of the problem of metallic diffusion on the NRL predisperser grating. SSL scientists contributed to the analysis of the out-gassing properties and contamination potential of the S-13G paint used on the

Skylab and recommended the solution to this problem. Also, SSL scientists served as consultants in setting operation procedures and automating many of the quality tests and the vacuum bakeout of ATM materials. The SSL Experiment Scientists have provided the liaison between the in-house contamination program and the external PI's and have performed a contamination analysis on some of the flight experiment instrumentation.

## Flight Measurements Program

As mentioned previously, many experiments apparently had been adversely affected by contamination. Reports of window fogging and particulates in the vicinity of spacecraft were made by the first astronauts. Photographs of waste water and urine dumps were particularly spectacular. Astronauts reported their inability to see even bright stars in daylight. It was believed by many that a cloud of contaminating material follows the spacecraft, and, in a sense, this is the case. Unfortunately, there is little qualitative or quantitative data on the phenomena responsible for these observations.

A study was made of previous manned and unmanned spacecraft on which contamination problems had been reported. It was found through informal discussions with experimenters and program managers that in all cases in which contamination appeared to deposit on a surface, the surface either was partially enclosed in a canister containing the suspected source, or the surface was oriented so that the suspected source was in its line of sight. Optical surfaces that have been protected by baffling them from outgassing sources have performed for years without apparent degradation; e.g., the Orbiting Astronomical Observatory (OAO) telescope mirror. Some backscattering by the collision of outgassing molecules with atmospheric molecules will occur, and the contamination threat from such collisions is still being evaluated.

The mass spectrometers on Apollo 15 and 16 indicated a molecular flux of  $10^8$  molecules/m<sup>2</sup>/sec/sr (mostly H<sub>2</sub>O and CO<sub>2</sub>) from a solid angle that did not include the spacecraft. It is believed that these molecules evaporated from the ice crystals resulting from water and urine dumps in the vicinity of the spacecraft.

Attempts were made on the Apollo 15 and 16 missions to photograph the light scattered from debris in the vicinity of the spacecraft both before and after a dump. Scattered moonlight created considerable interference because

it was not possible to keep earth, sun, and moon light off the window. Therefore, only an upper limit on the scattered-light background could be established; however, this upper limit was within a factor of two or three from the zodiacal and intergalactical background before the dump. Stars as faint as  $m_v = 6.5$  were photographed with an 18-mm f/0.9 lens, and the limiting factor was photon starvation rather than background fog. Therefore, the reported inability of the astronauts to see faint stars must be attributed to factors other than a contamination cloud.

The decay of the dump cloud brightness was measured and found to be much slower than expected. This is attributed to the dump nozzle freezing, thus greatly prolonging the time required for the water to leave the spacecraft. In other words, the spacecraft has a source of particulates that can last for as much as an hour or more. This makes unattractive the prospect of time-lining overboard dumps to prevent interference with astronomical data. More definitive data on the behavior of this ice cloud will be obtained from the UV spectrophotometer on Apollo 17.

A set of contamination experiments was recommended for the Skylab flight as corollary experiments. These experiments include the following:

1. T-027A Sample Array, which will expose a set of optical samples and recover them for subsequent analysis.
2. T-027B/S-073 photometer to measure the light scattered from any debris cloud in the vicinity of the spacecraft.
3. T-025 coronagraph to observe particulate debris and measure the forward scatter from any contamination cloud.
4. T-030 mass spectrometer to determine the ambient molecular species (not approved for flight).

Even though the experiments were developed by external PI's, the SSL has been instrumental in their development and will use the experiment data to analyze the induced atmosphere around the Skylab. Several SSL scientists are guest experimenters on the T-027A Sample Array.

It was also recognized that real-time, in-situ measurements of contamination deposition were essential in making operational decisions, such as the opening of aperture doors on the ATM and EREP, as well as to detect

transient contamination layers which could deposit during orbital exposure but reevaporate before the recovery of T-027. The SSL developed a flight-qualified QCM for this purpose. Two such units will monitor the ATM sunshield near the aperture doors, four will monitor the region around the EREP, and two will be mounted on the T-027A Sample Array. Such units can detect the deposition of a monolayer of contaminant.

The possibilities have been explored of using other experiments on the Skylab to detect and measure contamination effects. Of course, if none of the experiments reveal any effects of contamination, this will verify that we have been successful in our primary endeavor; i.e., anticipating and eliminating such problems. Several possibilities exist in which an experiment may detect and measure parameters useful to our study of the behavior of the induced atmosphere. One such possible experiment is the S-191 infrared spectrophotometer which, if oriented properly, may be able to detect and measure the column density of water vapor in the vicinity of the Skylab. In addition, photography by the astronauts of targets of opportunity, such as vent plumes and contaminated windows and surfaces, has been requested.

Although this total set of flight experiments will still leave much to be desired, it is believed that it will resolve the most important issues concerning the deposition of contaminants and the scattering from particulates.

## Ground-Based Measurements Program

A major effort has been made to use every available opportunity to learn as much as possible about the potential contamination problems from ground tests of the Skylab hardware. Even though all flight conditions cannot be simulated in such tests (most notably the effect of zero-gravity), many can. Furthermore, with a system as complex as the Skylab, detailed analyses of contamination sources, transport, and effects require many simplifying assumptions. Therefore, a combination of test programs backed by a strong theoretical and laboratory research effort is essential to the understanding of the problems.

An early test to estimate the contamination produced by hypergolic reaction control system (RCS) engine firings was conducted in conjunction with an MSC engine plume test in the large Chamber A at Houston. A 44.8-N (100-lb) Lunar Module (LM)-RCS thruster fueled with Aerozine 50 was fired for 100 sec. SSL personnel were responsible for deploying and analyzing passive contamination samples. Severe contamination was observed on all samples, even those not facing the plume. This was caused partly by reflection of the exhaust plume from the chamber cold walls and partly by the

reevolution of condensed reaction products from the walls as they were warmed before repressurization of the chamber. Significant evaporation of contaminants from the surfaces was also observed before the measurements could be completed. The primary result of this test was to evaluate the usefulness of various contamination measurements and help refine handling and instrumentation techniques. The necessity of real-time monitoring was clearly demonstrated.

A follow-on test is being planned for the chamber at Lewis Research Center, in which in-situ measurements will be made in a chamber with walls at 4°K, which will serve as an almost perfect molecular sink. The purpose of the test will be to determine whether RCS firings will produce sufficient backscatter to contaminate surfaces behind the plume line. This information will be used to assess the contamination expected if the Service Module (SM) RCS engines are used for orientation control during the EREP mission. The SSL will be responsible for the instrumentation.

There was considerable concern over the proposed use of the MSC Chamber A for the ATM thermal vacuum tests because the chamber had been used for a variety of purposes, and cleanliness had never been a major concern. Inspections of the chamber revealed conditions totally unsuitable for testing of sophisticated optics such as the ATM. A major cleaning operation, with white glove inspection teams, was instituted to prepare the chamber. A series of tests, V-1, V-2, and V-3, were conducted to verify the cleanliness of the chamber. Personnel from the SSL were instrumental in this operation and provided a variety of instrumentation to detect contamination deposition. This instrumentation included QCM's, passive samples such as mirrors and flats, quadrupole residual gas analyzers (RGA's), and a Real Time Contamination Monitor (RTCM) consisting of a thermally controlled mirror whose reflectance and scattering of L-alpha [121.6 nm (1216 Å)] radiation is continually monitored. Some deposition of material was detected on very cold surfaces and could be correlated with events such as gaseous purges and leaks in purge lines, but the material quickly reevolved, indicating no residual contamination. These inputs, together with other measurements, verified that the chamber was suitable for ATM testing.

SSL personnel also provided and operated similar instrumentation during the ATM thermal vacuum tests, TV-1, TV-2, and TV-3. A technique was developed for operating the quadrupole mass spectrometer head through an inductive link which permitted long cables to be used between the head and the RF-dc generator, which had to be outside the chamber. This allowed the installation of the sensing head near the ATM aperture doors for sensing

any outgassing material released when the doors were opened. No significant contamination was found during these tests, indicating that the precautions taken were sufficient to prevent any degradation of the experiment optics.

The SSL also developed a device called a Passive Contamination Monitoring Device (PCMD) that consists of a number of racks, each containing several optical surfaces. These surfaces were carefully measured into the far UV before installation in a special mount on the ATM film access door. The samples are subjected to the same environment as the ATM optics throughout the entire ground handling, storage, and testing. Racks are extracted at various milestones during the program and remeasured to infer the condition of the ATM optics. Thus far no significant change has occurred, indicating that the ground handling procedures have been adequate.

One of the most difficult problems confronting the Skylab was the waste management system. It is necessary to dispose of considerable quantities of waste water and other matter from the crew use and from the Environmental Control System (ECS) condensate. It was originally proposed to dump the ECS waste overboard at a high velocity for rapid clearing and to time-line the experiments accordingly. This was later modified to dump the condensate directly into the Orbital Workshop (OWS) tank because of the uncertain clearing time and the possibility of freezing on the cold EREP detectors exposed to the plume. The molecular sieve dumps automatically every 15 min, but its products presumably are all gaseous. Wardroom water and urine were to be bagged and stored in the OWS tank. A large quantity of liquid water from line purge will be dumped into the OWS tank at the beginning and end of each mission. Also, large quantities could be released in the event of bag rupture. There was concern over the possibility that ice crystals formed during the release of water into the OWS tank and other solid debris would be discharged more or less continuously from the vents. Such a discharge could result in a luminous cloud surrounding the spacecraft, which could seriously interfere with many of the Skylab and ATM experiments.

Working closely with MSFC Central Systems Engineering (CSE) personnel, SSL personnel analyzed this problem and recommended that fine mesh screens be installed to prevent particles larger than a few micrometers from escaping. The escape of smaller particles would be retarded by these screens, which would allow most of the smaller particles to melt or become entrapped before they could escape the vent.

The performance of these screens could only be estimated, and it was believed that full-scale operational tests were necessary to investigate their clogging, corrosion, and overall performance. In addition, tests were

developed to measure the size and velocity distribution of ice crystals resulting from water jets emerging from various nozzles and of particulate generation from the molecular sieve and the fecal dryer. This group of tests comprised the Skylab Contamination Ground Test Program (SCGTP) and was conducted by the Martin Marietta Corporation under the direction of Dr. Gause, of the Astronautics Laboratory at MSFC. The SSL was responsible for the instrumentation.

Several unique instruments were developed for this test series. A holographic camera was set up in the test chamber. A TRW double-pulse laser was mounted outside the chamber, and a 70-mm electric Hassleblad camera without lens was used inside the vacuum to record the holograms. Size and velocity data for particles larger than  $5\text{ }\mu\text{m}$  in a volume of several thousand cubic centimeters were obtained by microscopic examination of the reconstructed hologram. Other instruments included a scatterometer built by modifying a commercially available Gam Rad turbidity monitor, electrostatic detectors developed by Stanford Research Institute, QCM's, and an RTCM.

The most useful and unique instruments in this test series were a group of aerosol detectors developed by Dr. Knollenberg, a cloud physicist from the University of Chicago. These devices use laser scattering and extinction techniques and can automatically obtain size and velocity distributions for particles ranging from  $0.1$  to  $40\text{ }\mu\text{m}$ .

The results of these tests indicate that the screens will reduce the emission of particles to the point where no interference from a particulate cloud is expected.

## Summary

The Skylab/ATM program represents the largest, most sophisticated set of measurements ever attempted in space. The fact that it must operate in direct sunlight over the entire electromagnetic spectrum makes it extremely susceptible to contamination from particles in its vicinity and to deposition on optical surfaces. It is not an understatement to say that the future role of manned spaceflight will be adversely affected if the scientific measurements on the Skylab are degraded by contamination from the life-support system. An all-out effort has been made on the Skylab to eliminate every conceivable source of contamination. Some of the contamination requirements placed on the Skylab have necessitated expensive design changes and restrictive material



selection and may in some instances represent an "overkill" solution. However, the importance of cleanliness to this mission dictated these decisions to insure mission success. We have learned much about the contamination problems in the development and testing of the Skylab and are in the process of being able to analyze the potential contamination problems for future missions, such as the Large Space Telescope (LST) and other Shuttle payloads. This experience has already been incorporated in the High Energy Astronomy Observatory (HEAO) to prevent possible internal contamination problems by isolating the critical surface from the interior of the spacecraft. Design practices such as this and the improved understanding of the behavior of contaminants that will be obtained by analyzing the experiments on the Skylab may allow a relaxation of some of the costly practices presently required.

Instruments such as the IRTCM have been developed to fly in the Shuttle cargo bay and in the vicinity of critical experiments. This instrument combines an optical effects module — which can make in-situ measurements such as reflection, transmission, and scatter on a sample at two UV wavelengths — with a QCM, a quadrupole mass spectrometer, and an aerosol spectrometer. This instrument will be capable of detecting the presence of a contaminating atmosphere composed of both aerosol and molecular constituents; identifying the constituents; measuring the deposition rate, stay time, and amount deposited, and correlating this with the optical degradation. This instrument is presently undergoing engineering evaluation. Such an instrument will be extremely useful for making real-time operational decisions to prevent or minimize contamination.

The active cleaning technique has proved itself useful in the laboratory and may be required to rejuvenate optics such as the LST mirror if its performance becomes degraded.

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## V. ENVIRONMENTAL AND THERMAL DESIGN CRITERIA

This section discusses assignments within the SSL in the fields of meteoroid and radiation definition and protection and thermal effects expected on the Skylab. Also included is a review of thermophysics supporting research and technology. Important contributions to the Skylab design documents have resulted from these efforts.

# METEOROID INVESTIGATIONS

By Edward L. Shriver

The SSL has been assigned the task of defining the near-earth environment as a potential hazard to long-term orbiting spacecraft such as the Skylab. Three major efforts have been undertaken as a result of this assignment: Pegasus data evaluation, low-light-level television observations, and laboratory simulation of the obtained data to evaluate the effect on Skylab components. These are reported on the following pages.

## Pegasus Data Evaluation

The SSL played a key role in the Pegasus Project with the reduction and calibration of the data from the meteoroid experiment. The Pegasus series of satellites was launched in 1965 to investigate the near-earth meteoroid environment at altitudes ranging initially from 500 to 700 km above the surface of the earth. The prime mission of the spacecraft was to measure the meteoroid penetration frequency into three different thicknesses of aluminum. The results of these measurements proved basic in the formulation of the meteoroid flux model adopted by NASA for design criteria.

Although the Pegasus data were accepted as a tie point, the NASA criteria rely upon an extrapolation of nearly six orders of magnitude between these data and those determined photographically. An optical extension of photographic results into the small mass range is needed.

## Low-Light-Level Television Observations

The Astrophysics Branch of the SSL has undertaken a program of ground-based observations of meteors with low-light-level TV systems. These systems, using SEC vidicon intensifiers, have proved considerably more efficient than photographic cameras and now provide the only optical means whereby large statistical samples of faint meteors can be obtained.

Observations to determine the slope of the mass flux curve for meteors in the mass range of from  $10^{-2}$  to  $10^{-4}$  gm were conducted in Colorado in 1970.



The results of the TV observations have substantiated the design curve accepted by NASA in a region where no reliable data existed.

## Laboratory Simulation

The laboratory simulation has used two types of accelerating techniques, the light gas accelerating technique, which is capable of accelerating particles as large as  $10^{-1}$  gm to velocities of 10 km/sec, and the plasma accelerator, which is capable of accelerating particles that are  $10^{-6}$  gm to velocities of 10 km/sec. Recently a third technique has been investigated which is a combination of these two and appears to be able to launch  $10^{-6}$ -gm particles up to 20 km/sec.

Using these techniques, the hypervelocity laboratory has investigated the OWS tank wall, critical bumper thickness, impacts on the ATM and OWS solar cells, multiple docking adapter (MDA) structures, MDA windows, Skylab cables (six types), and honeycombed double-sheet instrument unit panels.

When the OWS was first proposed, a joint test program was initiated by the SSL and the Astronautics (ASTN) Laboratory to investigate the vulnerability of the S-IVB tank wall. There was concern that an impact could cause the polyurethane foam insulation adjacent to the aluminum outer wall to ignite and burn in the pure  $O_2$  atmosphere; tests proved that this was indeed the case. Any impact that penetrated the aluminum hull resulted in a fire that burned to depletion of either fuel or oxidizer. Furthermore, the analysis showed that the probability of the tank wall surviving in the meteoroid environment for 8 months was approximately 0.8. This led to the decision to protect the OWS wall by deploying an aluminum meteoroid bumper. Also, a fire-retarding curtain was developed by the ASTN Laboratory, and its effectiveness was demonstrated in a subsequent test program.

The SSL made a study of the critical bumper thickness required to completely disintegrate a projectile. The experimental study was complemented by the development of a theoretical equation of state for aluminum which accurately predicted the pressure, temperature, and trajectories of the shock wave and release waves. These results were inputs to the final bumper design.

There was concern that meteoroid impacts on the solar cell panels could cause extensive shattering and open a string of cells. This was particularly true of the OWS solar cell array which contains many cells in series. An extensive test program was conducted on actual solar cell panels. It

was found that although extensive damage was encountered in the immediate vicinity of the impact, this damage was quite localized and the cells were remarkably invulnerable to cracking and catastrophic debonding. Analysis indicated no significant problem for the solar cell arrays.

One of the Skylab PI's requested that certain areas of the MDA pressure hull be reduced in thickness to improve the sensitivity of his experiment. The SSL tested the proposed structure and found that debris from the meteoroid bumper would readily penetrate the pressure hull. As a result, the request was denied.

Tests on the MDA window indicated vulnerability to meteoroid damage. Therefore, a cover will be used to protect the window during periods in which it is not in use.

Many cables between the ATM and the OWS are exposed either directly to the space environment or are encased in cable tunnels. The chance of a single wire being severed by an impact is negligibly small, but the spray particles from a meteoroid impact on the tunnel structure can be quite damaging to the wires. Since the tunnel represents a much larger cross section than a wire, this problem cannot be ignored. It was proposed that additional shielding, estimated to cost \$500,000, be added to increase the protection of these wires. An extensive test series was conducted in the SSL hypervelocity range in coordination with the ASTN and Astrionics (ASTR) Laboratories. The results of these tests indicated that the survival probability of mission critical cables was sufficiently high with the existing protection. Therefore, the expenditure of the additional \$500,000 was unnecessary.

Tests were run on many other Skylab components, such as the meteoroid curtain and honeycomb panels, to estimate their vulnerability to damage. Through this type of testing, the design estimates have been verified or inadequacies have been pointed out. In this way, design confidence in the Skylab system has been developed.

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# RADIATION ANALYSIS AND PROTECTION

By Martin O. Burrell

The SSL first became involved in the study of radiation effects on ATM film in 1967 when it was shown that protons in the trapped radiation belts could cause degradation to experimental film. At this time, the SSL carried out extensive experimental testing of proton radiation damage to anticipated films for several ATM experiments at three national facilities (Harvard University, Langley Research Center, and Oak Ridge National Laboratory) [1]. This work was the fundamental radiation effects data for several years until the Skylab experiments were defined. At this later date, MSFC, through extensive contractor effort, generated additional data from cobalt 60 gamma-ray sources. Most of these new data could be used only to establish the upper bounds of radiation damage from protons. After the Skylab definition, the SSL analyzed the radiation impact inside the complex geometry of the ATM and Skylab structure with materials and experiments on board.

Figure 19 shows the general procedures necessary to conduct such a meaningful evaluation of space radiation problems. The Skylab cluster is assumed to be in a 440-km, 50-deg circular orbit. The flight profile is for the last 8 months of 1973, a period near solar minimum. Potentially damaging radiation for this mission included trapped protons, trapped electrons, and galactic cosmic radiation. Solar proton events, while unpredictable, should have minimal effects on the mission because of the low probability of the occurrence and shielding by the magnetosphere. Figure 20 presents the expected dose rates per day for the Skylab orbits when only a spherical structure of uniform thickness is used. Of course, the complex geometry of the Skylab cannot be depicted by such a simple analog, but the range of radiation effects can be anticipated.

In the actual calculations, the shielding afforded by the Skylab cluster is taken into account with a 5000-volume element mathematical model. To explain the role that the SSL played in this analysis, it will suffice to refer to Figure 19. SSL employees provided the space radiation environment coupled with the mission profile. The radiation transport methods were developed by scientists in the SSL [2, 3, 4, 5]. However, because of the limited number of SSL personnel available and the engineering problem of utilizing thousands of blueprints to depict the Skylab cluster geometry, mass,

and material distribution, a contract was awarded the Lockheed Georgia Company to develop the 5000-volume element mathematical model [6, 7]. From this model, using SSL environmental data and radiation transport methods, the radiation environment at interior points of the Skylab system was determined. Using the aforementioned information, the response of photographic film to various energies and components of the radiation was incorporated in order to arrive at the damage (fogging) effect to various onboard films. At this point, the PI had to determine whether the damage or effect was allowable. If not, an estimate of the necessary shielding was made by the SSL, and the above process was repeated to determine whether the film was protected well enough. Sufficient space is not available in this document to consider this matter in the depth in which it was treated.

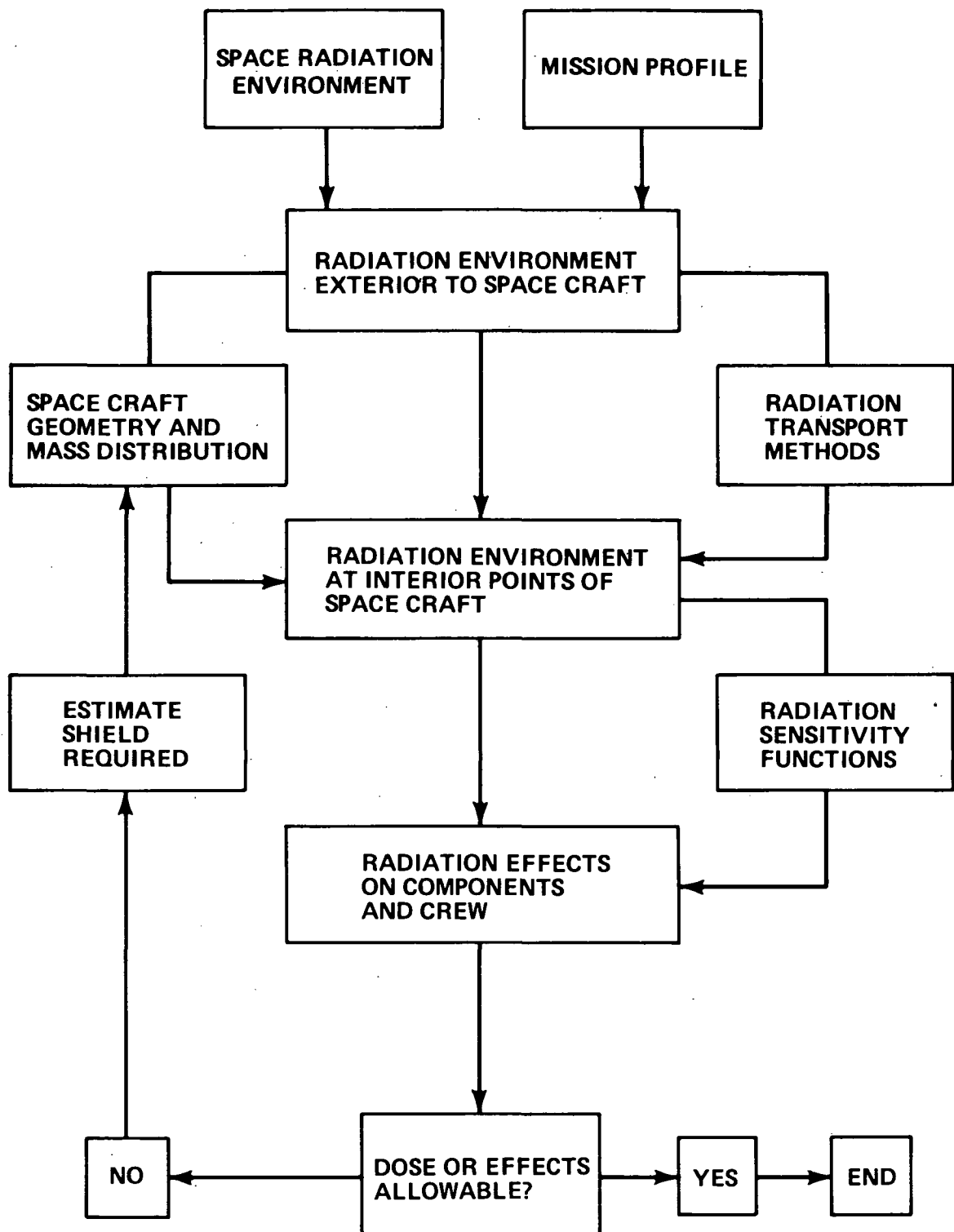


Figure 19. Flow chart for analysis of space radiation effects.

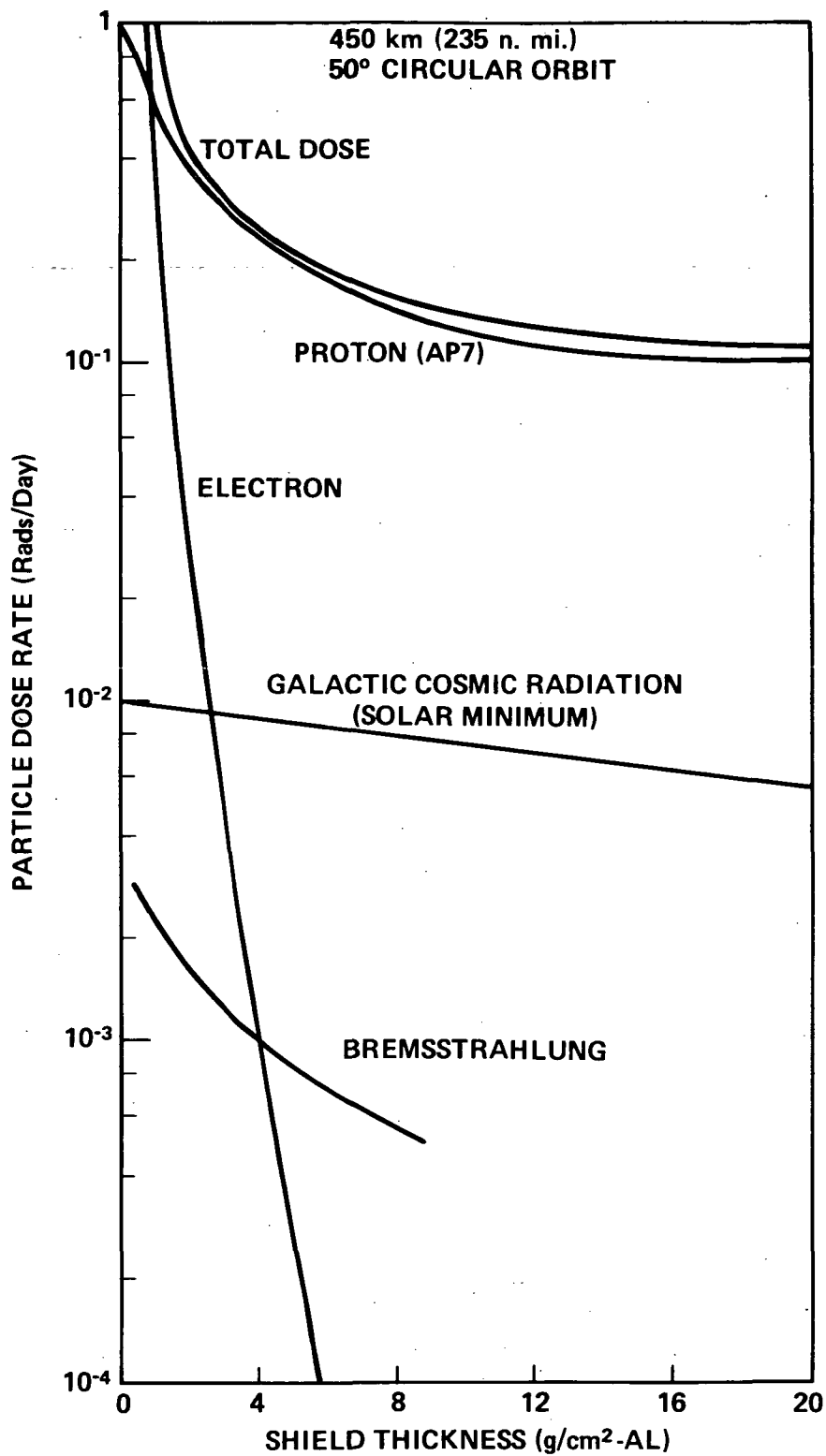


Figure 20. Radiation dose as a function of shield thickness.



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# THERMAL ENVIRONMENTAL CRITERIA

By Paul Craven and Allen Gary

The thermal environment of the Skylab was described by the SSL in NASA TM X-53957, Space Environment Criteria Guidelines for Use in Space Vehicle Development (1969 Revision). Values of the solar constant at 1 AU, the albedo, and earth-emitted thermal radiation were given. Variations in albedo and earth-emitted thermal radiation were specified in terms of the component thermal time constant. The SSL also agreed to investigate the use of standard deviations to present the variation in albedo and earth infrared.

The SSL was asked to investigate the effect of the earth's albedo on the Skylab's sun acquisition sensors to determine whether it could cause the sensors to lock on the earth or cause pointing errors. The investigation showed that the albedo's effect would not be great enough to cause either of these.

# THERMOPHYSICS SUPPORTING RESEARCH AND TECHNOLOGY

By

Gary M. Arnett, Donald R. Wilkes, and Barbara Facemire

The SSL's Skylab involvement in the area of thermophysics SRT has been mainly in a support capacity for the Skylab thermal designers. Data have been requested and supplied on the thermal control coatings, including their optical properties and environmental stability. The overall SSL experimental capability and facilities in this area have contributed to providing the required data on thermal control surfaces. Many years of experience in the area of environmental effects on thermal control surfaces dictated the need for in-flight optical properties measurements, using techniques identical to those used in the many thousands of hours of laboratory tests. This would not only give actual flight data on thermal control surfaces but would also validate all laboratory testing. The major problem in making these required in-flight measurements is the need for a portable spectrorreflectometer. A 5-yr effort has been invested in developing a laboratory model of such a spectrorreflectometer. NASA Headquarters has been very interested in flying this instrument on the Skylab (T-031). This interest was aided by a request from the Skylab thermal designers to make in-flight measurements on the life-support system radiators using the T-031 reflectometer. Designs for flight hardware have been completed, and a qualification flight unit is being fabricated. As of yet, however, the T-031 project has not been approved for the Skylab.

The T-031 spectrorreflectometer, as now designed, provides eight-channel spectral reflectance measurements over the solar spectrum. The data are read out on the face of the instrument for recording by the astronaut over his voice link. Together with its internal battery pack, this feature makes the instrument completely portable.

At present, in-house environmental testing is continuing and will provide any needed data on thermal control surfaces. In-house efforts include investigating the long-term (approximately 10-yr) stability of thermal control surfaces in a simulated space environment. The unique facility for environmental testing includes computer-controlled measurements and monitoring functions. In-house testing also includes determining the solar wind effects on thermal control surfaces.

Several PI's for the Skylab/ATM experiments expressed concern that some thermal control coatings used on the Skylab might cause serious contamination problems because of outgassed products. The SSL was asked to investigate the severity of outgassed products from thermal control coatings. It was shown that S-13g, the primary thermal control coating on the Skylab, could produce outgas products which altered the optical properties of first surface mirrors. It was also shown that the coating, after being heat-treated for a period of time, no longer outgassed. Similar tests have shown that Cat-a-lac black produces no optical problems. The SSL is continuing this effort to examine for outgassed products all thermal control coatings used on flight hardware.

Involvement in the area of phase change thermal control began 6 yr ago, and research in this area was instrumental in bringing this technology to a stage of development permitting application to the Skylab. The effect of the space environment on solidification and liquidation was investigated. It was shown that the major effect in most phase change materials (PCM's) was the lack of gravity-driven convection and, thus, a decrease in heat transfer. This problem has been partially overcome by the use of metallic filler materials, which effectively increase the thermal conductivity of the PCM system. The SSL effort has included such areas as supercooling, nucleation, and crystallization. A NASA contractor report (NASA CR-61363) published in September 1971 and titled Phase Change Materials Handbook, contains PCM property data and thermal capacity design data.

Because of the background just mentioned, the SSL has provided data and state-of-the-art information so that PCM thermal capacitors were considered feasible for use on the Skylab as part of the overall thermal control system. Members of the SSL worked with the Skylab thermal design engineers on a consulting basis in the design and development of the thermal capacitors. During this effort, thermocouples were placed in the airlock thermal capacitor to obtain in-flight data on PCM system performance. Because of the many contacts developed during this research, when problems (such as capacitor rupture due to excessive expansion) arise, the SSL provides data or is able to put the designers in touch with the persons who can provide the most assistance.

## VI. ADDITIONAL SSL INVOLVEMENT IN THE SKYLAB

Three other activities described in this final section complete the picture of major contributions to the Skylab by scientists and engineers in the SSL. The first is the development of a Proton Spectrometer to measure the flux of energetic protons between 18.5 and 400 MeV. In the remaining two, the SSL has furnished Experiment Scientists to work with the PI's on two scientific experiments. They are S-073, Gegenschein/Zodiacal Light, designed to measure the surface brightness and polarization of the night glow over a large portion of the celestial sphere in the visible light spectrum to determine the extent and nature of the spacecraft corona during daylight, and S-183, Ultraviolet Panorama, designed to obtain wide field-of-view photographs of individual stars and extended star fields in the ultraviolet. Table 7 lists the persons involved in these three areas.

TABLE 7. ADDITIONAL SSL INVOLVEMENT IN THE SKYLAB

Experiment or Function	Principal Investigator	SSL Role
Proton Spectrometer	Dr. G. Guenther, University of Alabama in Huntsville	Dr. T. Parnell, Project Scientist; Mr. G. Detko, Project Engineer
S-073 Gegenschein/ Zodiacal Light	Dr. J. Weinberg, Dudley Observatory	Dr. A. Gary and Mr. P. Craven, Experiment Scientists
S-183 Ultraviolet Panorama	Dr. G. Courtes, Laboratoire d'Astronomie Spatiale	Mr. H. Atkins, Experiment Scientist

# PROTON SPECTROMETER

By Thomas A. Parnell

A circular orbit of approximately 450-km altitude and 35-deg inclination optimizes the parameters of spacecraft mass and orbital lifetime and, thus, has been chosen for the Skylab and other future missions, such as the HEAO. One disadvantage of this orbit is that it intersects a low region of the inner Van Allen radiation belt called the South Atlantic anomaly, which contains a large flux of electrons and high-energy protons. In this orbit, the protons contribute the majority of the radiation dose behind a shielding thickness of 0.3 cm of aluminum and will be responsible for most of the radiation-induced darkening of film on the Skylab, especially for the ATM experiments. These protons will also cause much of the gamma-ray background in spacecraft materials, which will limit the sensitivity of the gamma-ray experiments on the HEAO. The flux of these high-energy protons is not well known because of the steep gradient of the flux with altitude and the lack of previous definitive measurements in the South Atlantic anomaly region with instruments designed to measure the protons.

The purpose of the Skylab Proton Spectrometer is to measure the ambient flux of energetic protons and electrons on the outside of the spacecraft and especially to measure the spectrum of those protons that are energetic enough to penetrate the Skylab structure and cause radiation damage to the ATM experiment film. The data will be useful in film scheduling and post-flight film processing and analysis. It will also be needed in planning future missions, especially the shielding necessary for radiation-sensitive material such as film.

Protons between 100 MeV and 400 MeV will be emphasized in the measurement because previous data are uncertain at these energies and not available above 170 MeV. The measurement has been extended down to 18.5 MeV because only the lower-energy particles are likely to exhibit time variations which can be studied during the lifetime of the Skylab.

Even though energetic electrons outnumber protons in the South Atlantic anomaly, they contribute only 10 percent to the radiation dose inside the spacecraft. However, the existence of these electrons strongly influences the design of the Proton Spectrometer, and special techniques must be used to avoid saturation of the scintillation counters and circuits by the numerous electrons.

To measure protons in the intense electron environment, a particle must fulfill a set of logic requirements to be counted. A logic scheme has been developed to divide the 18.5-MeV to 400-MeV energy spectrum into eight regions, store all proton events in eight 10-bit binary accumulators, decode the digital information, and read out the results. The instrument will also measure the electron spectrum from 2 MeV to 10 MeV in three channels.

The PI is Dr. Godehard A. Guenther of the University of Alabama Research Institute. Other members of the Proton Spectrometer Team are Dr. Thomas A. Parnell, Project Scientist; Mr. George J. Detko, Project Engineer; and several other scientists and engineers within the SSL and other Science and Engineering laboratories at MSFC.

## EXPERIMENT S-073 – GEGENSCHNEIN/ZODIACAL LIGHT

By Allen Gary and Paul Craven

The goal of a current effort in this area is to maintain an awareness of the scientific objectives of the S-073 Gegenschein/Zodiacal Light Experiment in order to support the MSFC Program Development Directorate, the Skylab Office, and the mission support group for the S-073. .

Participation by the SSL in the stray light suppression test of the sunshield and optics and a review of the current status of the instrument has led to support of the redesign of the sunshield. Participation in the Corollary Experiment EOP (Experiment Operating Plan) and discussions with involved persons are being continued. Experiment Requirements Documents (ERD's) , are reviewed, as needed, to insure scientific integrity.

Through the support of the Office of Space Science (OSS), the construction of a ground-based photoelectric polarimeter similar to the S-073 has been partially completed. The photometer will be used by the SSL to support the Skylab experiment and the international zodiacal light program. The instrument will determine the atmospheric contamination of ground-based observations of the interplanetary dust cloud. The observations will be in conjunction with the S-073 and for a scientific evaluation of the S-073 system. The polarimeter will help to provide zodiacal light and airglow observations to determine the correlation between ground-based and space observations.

A theoretical program is continuing for the analysis of observed radiance and polarization in terms of light-scattering models for the interplanetary dust cloud. A proposed NASA Technical Note entitled A Study of Zodiacal Light Models has been written, which unifies the models appearing in the literature and presents the SSL work.



# EXPERIMENT S-183 — ULTRAVIOLET PANORAMA

By Harry L. Atkins

Experiment S-183 — Ultraviolet Panorama is part of a continuing series of UV spectrography experiments of the Laboratoire d'Astronomie Spatiale (LAS) of Marseilles, France.

Figure 21 is an overall schematic of the equipment. The experiment is designed to use the articulated mirror system of the Skylab experiment S-019. This mirror system is capable of tilt and rotation and is used to reflect starlight into the entrance pupil of the S-183. Several star fields selected for the S-019 have also been chosen for the S-183 in an attempt to correlate the data from the two experiments.

Light from a 7-deg by 9-deg star field is focused by means of an elliptical mirror onto a grating, which diffracts the light into a spectrum. Two bandpasses at 190 nm and 300 nm are selected, using a spherical mirror which is physically masked to give the proper bandpasses. The spherical mirror focuses these bandpasses onto an array of spherical and cylindrical lenses, which acts as Fabry field lenses and focuses the light onto a UV-sensitive film (SC-5). This combination gives the type of image indicated in Figure 22. This schematic indicates that the images for both the elliptical and spherical mirrors are rectangular. This is a result of the optics, which gives a two-bandpass image of the entrance pupil. The cylindrical and spherical lenses give a rectangular image of, for example, a nebulae. However, the spherical lenses give a composite of images, whereas the cylindrical lenses give a continuous image along the longitudinal axis. In both cases the intensity and length of the spectral image is dependent upon the reflection and/or transmission properties of the spectrograph and the SC-5 film, the size of the source, and the intensity of its UV emission in these spectral regions. In general, the spherical lenses are more efficient for extended sources like nebulae, and the cylindrical lenses are more efficient for point sources like stars.

The experiment is designed to do a UV sky survey in three bandpasses in an effort to study hot stars. The 190-nm region is located in a UV region that is less affected by interstellar blanketing. The 300-nm bandpass is

designed to be near the U bandpass of the Johnson UBV ground-based photo-electric photometry system but out of the regions of the Balmer discontinuity. The results will be used to study phenomena such as interstellar reddening and color indices. Also, the results will be compared with ground-based astronomy as well as other space data, such as OAO (Orbiting Astronomical Observatory) data.

The optical arrangement gives two stellar images of approximately 60-nm halfwidth corresponding to the two bandpasses at 190 nm and 300 nm. The film will give a permanent record of the stellar images as well as a calibration source. The film is then scanned using a microdensitometer to give an average intensity over the chosen bandpasses.

In addition to the preceding bandpasses, the design uses the Skylab data acquisition (Mauer) camera, which is attached to the spectrograph, to obtain data in a bandpass region of approximately 36.5-nm halfwidth centered at 257 nm. This is designed to be an integral part of the scientific experiment, in addition to serving as a star-field identification source, because the image appears as a point source in comparison to the SC-5 spectrograph pictures.

A more thorough explanation of the experiment is given in the Skylab Experiment Operations Handbook (November 1971) published by the MSC.

The SSL is furnishing an Experiment Scientist whose involvement in the program is generally to provide local scientific assistance and certain specific scientific information. The following are examples.

## Stellar Distribution

A computer program was initiated which gave plots of the entire sky in 15-deg by 15-deg fields for all stars of spectral types OBA and a magnitude of less than seven. Figure 23 shows such a plot for the stars with the approximate spectral types. Another plot for the same region gives the number 0-7, which represents the stellar magnitudes. Also, a computer listing is given which states the number of stars in each 15-deg by 15-deg plot. This was an initial attempt to determine the maximum density of appropriate stars.

## Skylab Field-of-View Plots

The areas of the greatest concentration of stars and the times they are available from Skylab orbit are both important. Thus, another program (borrowed from the S-019) was initiated that gives these windows. Figure 24 shows such a plot, with the hashed area giving the area of the sky available for observations during the entire orbital night. The letters designate restraints; the numbers are the star fields identified by the LAS as their objectives and were obtained, in part, with the stellar distribution computer plots just explained. This program is being supplemented by an MSC/Martin program to include updated Skylab orbital parameters. The latter, now being furnished to the SSL by the MSC, is a computer printout of the observable stars and the length of time they can be observed. This adds to the ability to select star fields. For example, a high-priority star field that is observable for one-half of a Skylab night is more important than a less important field that is observable for the entire night.

## Other Activities

The Experiment Scientist has been attending several PI meetings and LAS working group meetings, as well as MSFC and MSC Skylab simulations, at the request of the PI, Dr. George Courtes. He has been working closely with Dr. Michel Laget (postdoctoral employee at the Goddard Space Flight Center (GSFC), who will return to the LAS soon to resume work on the S-183.

In an effort to assist the PI on the status of Skylab activities relating to the S-183, the Experiment Scientist is in frequent contact with MSC personnel as well as the MSFC Skylab Experiments Office.

The Experiment Scientist is also deeply involved in ground-based astronomy in support of the S-183, both in France and at the SSL's 1.5-m telescope facility in Tucson, Arizona. He will be a member of the S-183 Mission Support Group and has been requested by the PI to serve as a member of the scientific data reduction team.

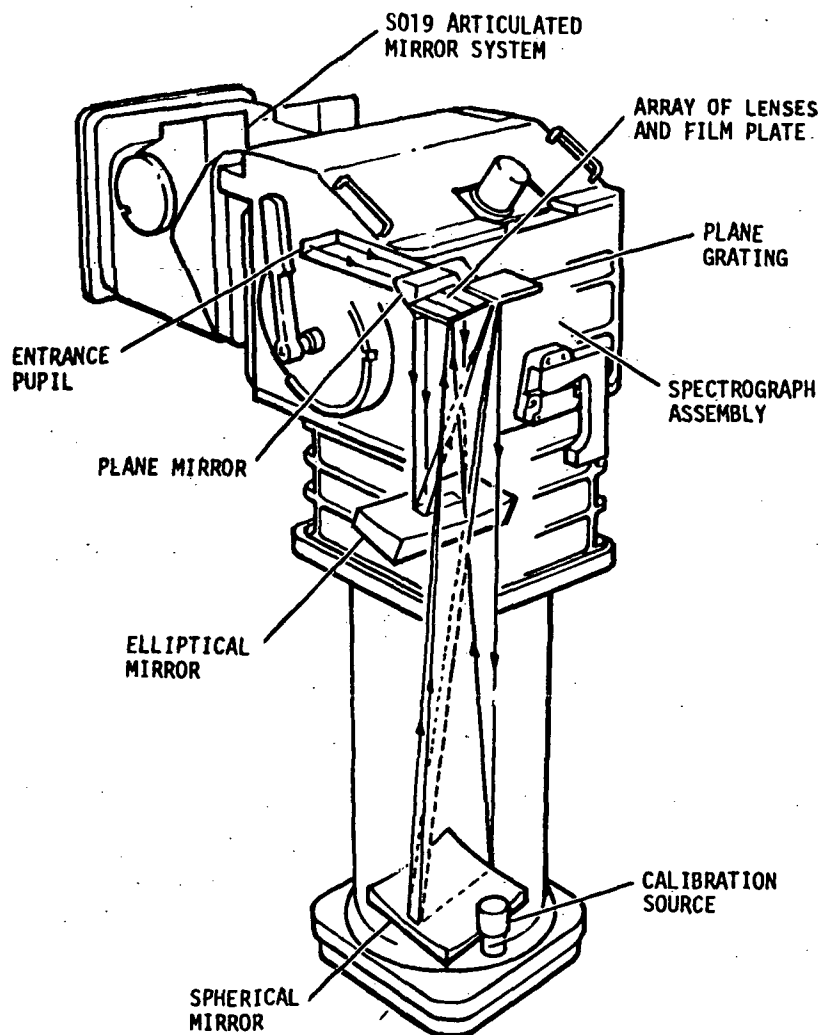


Figure 21. Spectrograph optics, S-183.

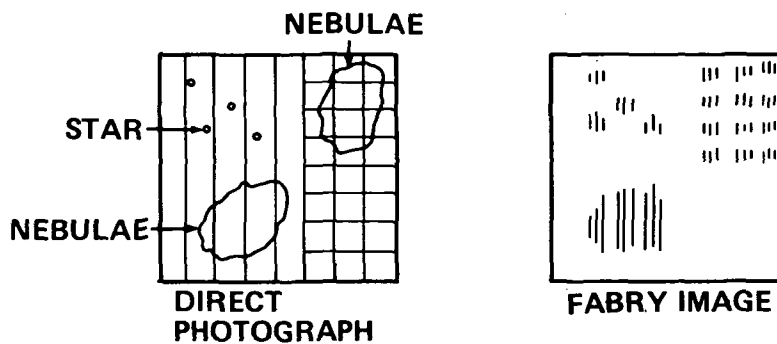


Figure 22. Comparison of direct sky photograph and Fabry images, S-183.

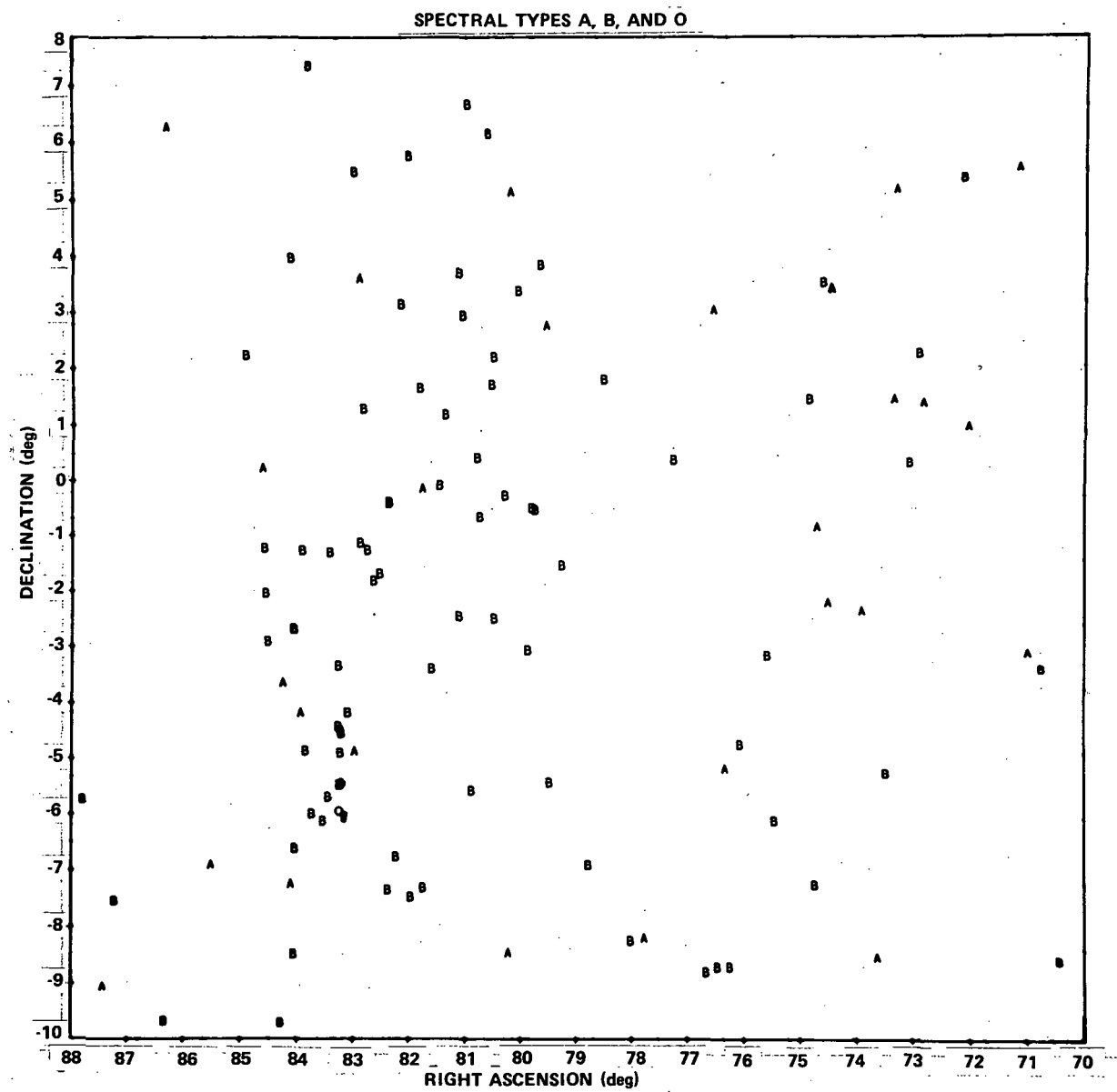


Figure 23. Plot of 15-deg by 15-deg star field, S-183.

PLOT GENERATED FOR MAY 2, 1973. REFERENCED TO AN APR. 30, 1973, LAUNCH.

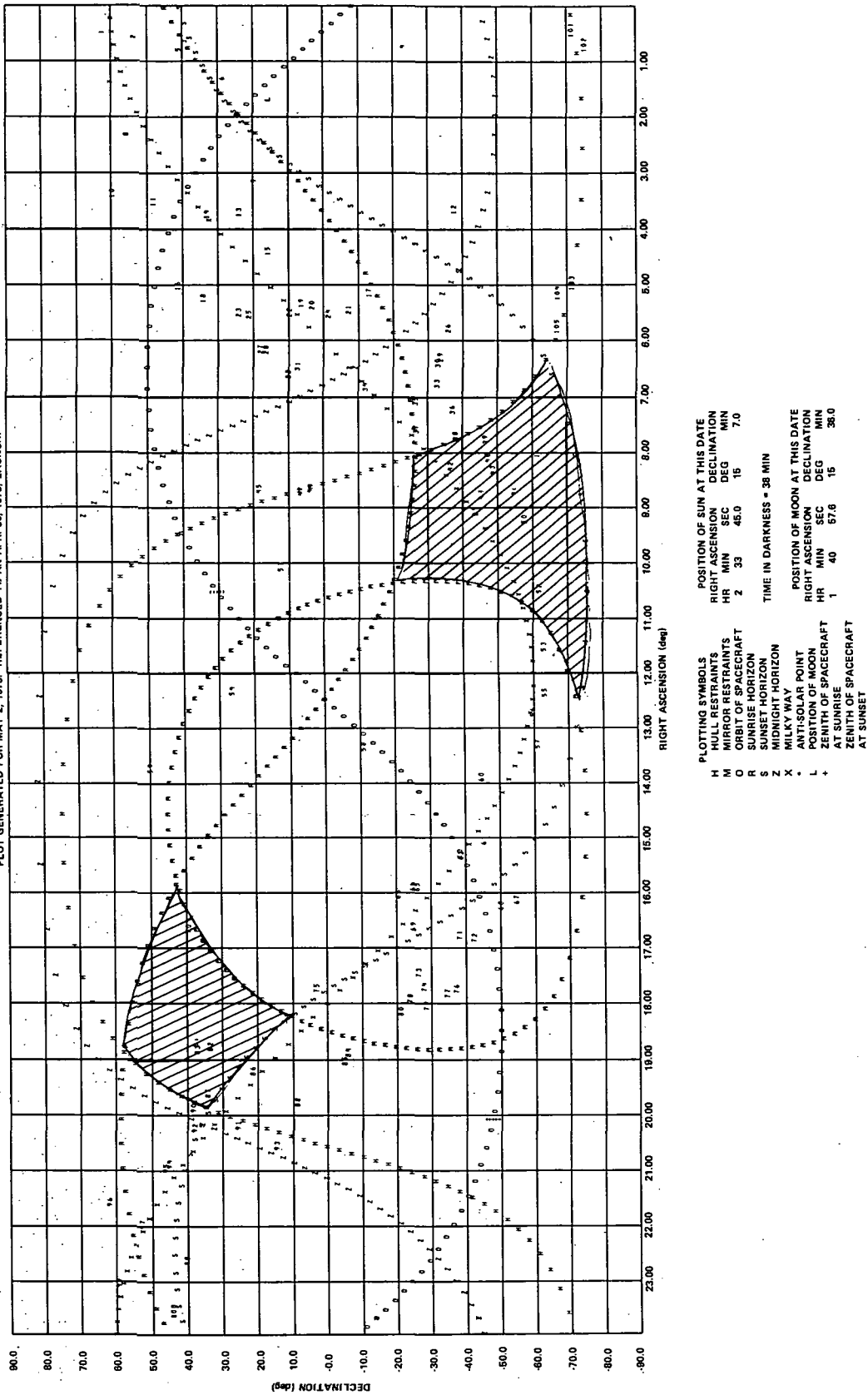


Figure 24. Skylab field-of-view plot.

SCIENTIFIC INVOLVEMENT IN SKYLAB BY THE  
SPACE SCIENCES LABORATORY OF THE  
MARSHALL SPACE FLIGHT CENTER

Edited by Carl E. Winkler

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W. HAEUSSERMANN

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